Digital Image Processing

Morphological Image Processing-part1
2023

Morphological Image Processing

- Morphological image processing is a collection of non-linear operations related to the shape or morphology of Objects in an image; Morphology is a broad set of image processing operations that process images based on shapes.

- Morphological techniques can be used for removing imperfections of regions in binary images such as those caused by noise, texture or inaccurate thresholding.
- Thinning in edge detection, Region filling, Edges-Linking are some important examples

- Morphological techniques are usually applied to Binary images (edges, boundaries, etc.) but can also be applied to grayscale images (Top-Hat Transform)

Some Uses of Mathematical Morphology

- image enhancement
- image segmentation
- edge detection
- skeletonization
- shape analysis
- curve filling
- general thinning
- corner detection
- Deep morphological networks ☺

Deep morphological networks

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Abstract

Mathematical morphology provides powerful nonlinear operators for a variety of image processing tasks such as filtering, segmentation, and edge detection. In this paper, we propose a way to use these nonlinear operators in an end-to-end deep learning framework and illustrate them on different applications. We demonstrate on various examples that new layers making use of the morphological non-linearities are complementary to convolution layers. These new layers can be used to integrate the non-linear operations and pooling into a joint operation. We finally enhance results obtained in boundary detection using this new family of layers with just 0.01% of the parameters of competing state-of-the-art methods.

Keywords: Mathematical Morphology; deep learning; edges detection; denoising.

1. Introduction

Modern deep learning approaches learn parameters of a series of linear and non-linear operators for a given task. The concatenation of these operators over multiple layers increases the depth thereby generalization power of neural networks. Similar to previous works [1, 2], our paper tries to incorporate new types

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Morphology: Quick Example

Image after segmentation

Image after segmentation and morphological processing

Morphological Operations

Some Morphological Operations

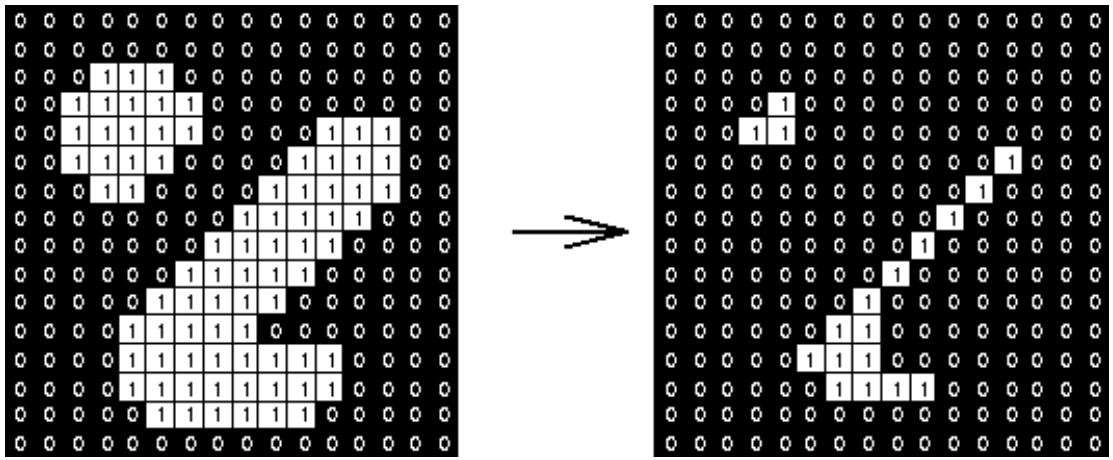
1- The Basic Operations:
- Erosion.
- Dilation.

2- The Compound Operations:
- Opening and Closing.

3- More Advanced Operations:
- Hit-and-Miss Transform.
- Thinning and thickening
- Corner Detection
- Region Filling
- Top-Hat Transform

Erosion

- Erosion ‘shrinks’ or ‘thins’ objects in a binary image.
- The manner and extent of shrinking is controlled by a structuring element.



- Structuring element:

1	1	1
1	1	1
1	1	1

Set of coordinate points =

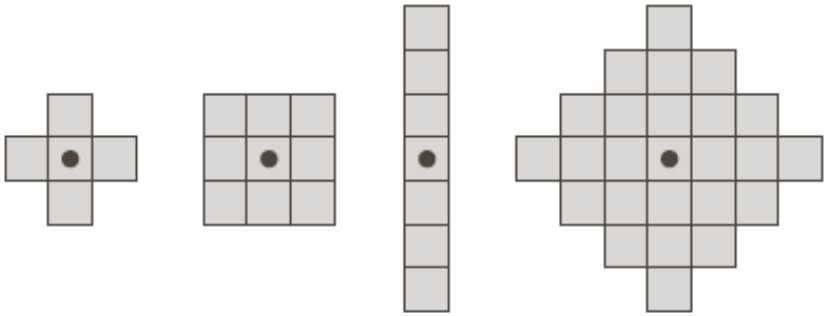
{ (-1, -1), (0, -1), (1, -1),

(-1, 0), (0, 0), (1, 0),

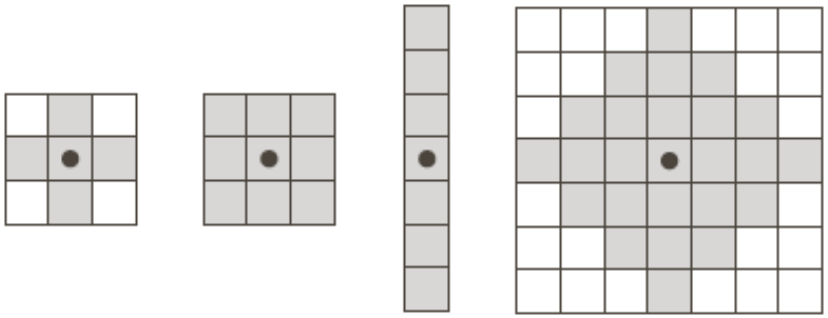
(-1, 1), (0, 1), (1, 1) }

Structuring Element

A structuring element is a small image – used as a moving window



Example Structuring Elements



Structuring Elements converted to rectangular arrays

Structuring Element

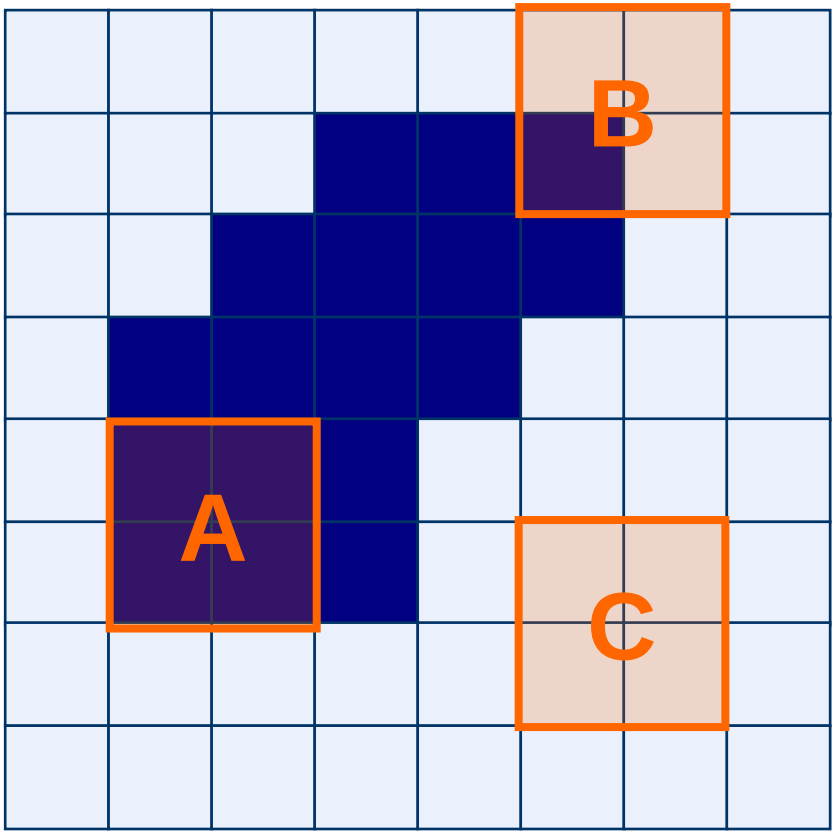
For simplicity we will use rectangular structuring elements with their origin at the middle pixel

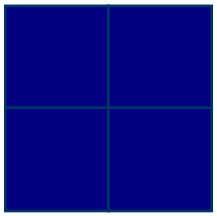
1	1	1
1	**1**	1
1	1	1

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

Structuring Elements: Hits & Fits





Structuring Element

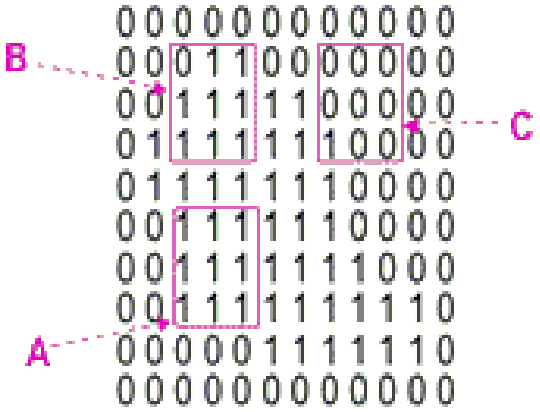
Fit: All *pixels* in the structuring element cover *pixels* in the image

Hit: Any *pixel* in the structuring element covers a *pixel* in the image

All morphological processing operations are based on these simple ideas

Structuring Elements: Hits & Fits

Consider each foreground pixel in the input image. If the structuring element fits in, write a “1” at the origin of the structuring element.



$$s_1 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \qquad s_2 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

		A	B	C
fit	s_1	yes	no	no
	s_2	yes	yes	no
hit	s_1	yes	yes	yes
	s_2	yes	yes	no

Hit: intersect the image in some pixels

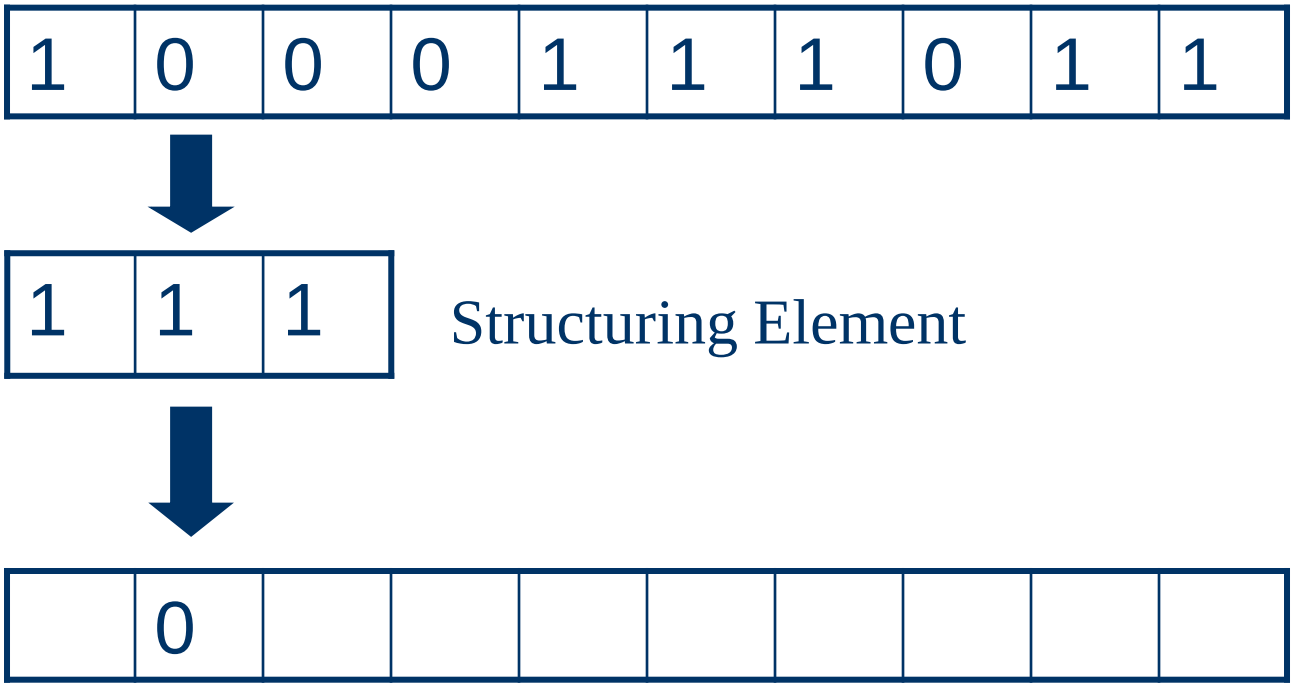
Erosion: !! تآكل

- The **erosion** of a binary image *f* by a structuring element *s* (denoted $f \ominus s$) produces a new binary image $g = f \ominus s$ with ones in all locations (x,y) of a structuring element's origin at which that structuring element *s* completely *fits* the input image *f*.
- The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

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

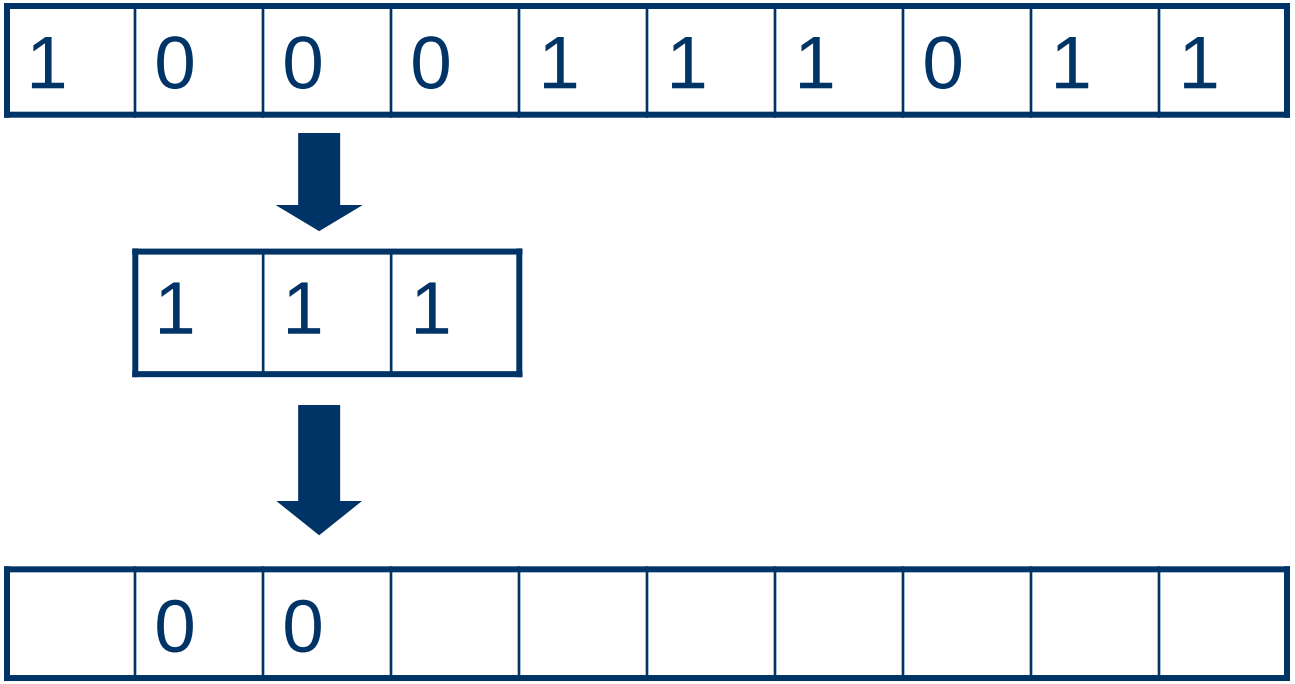
1-D Erosion example (1)

Input image

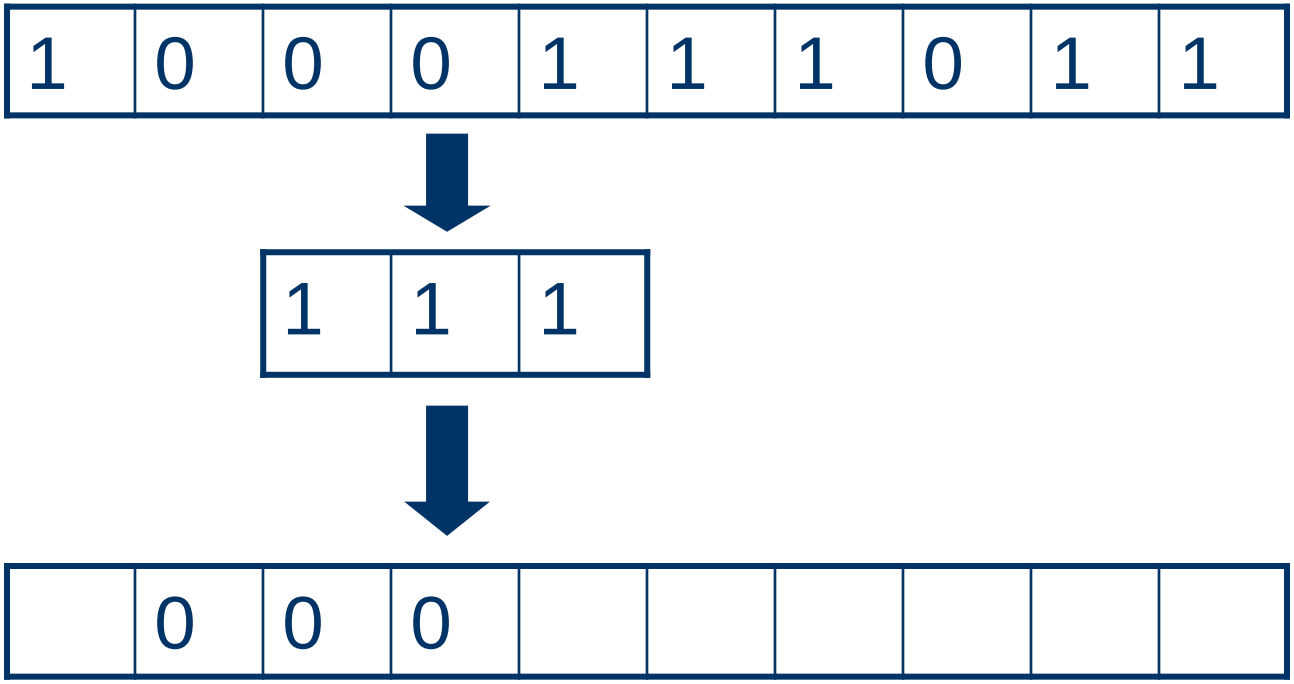


Output Image

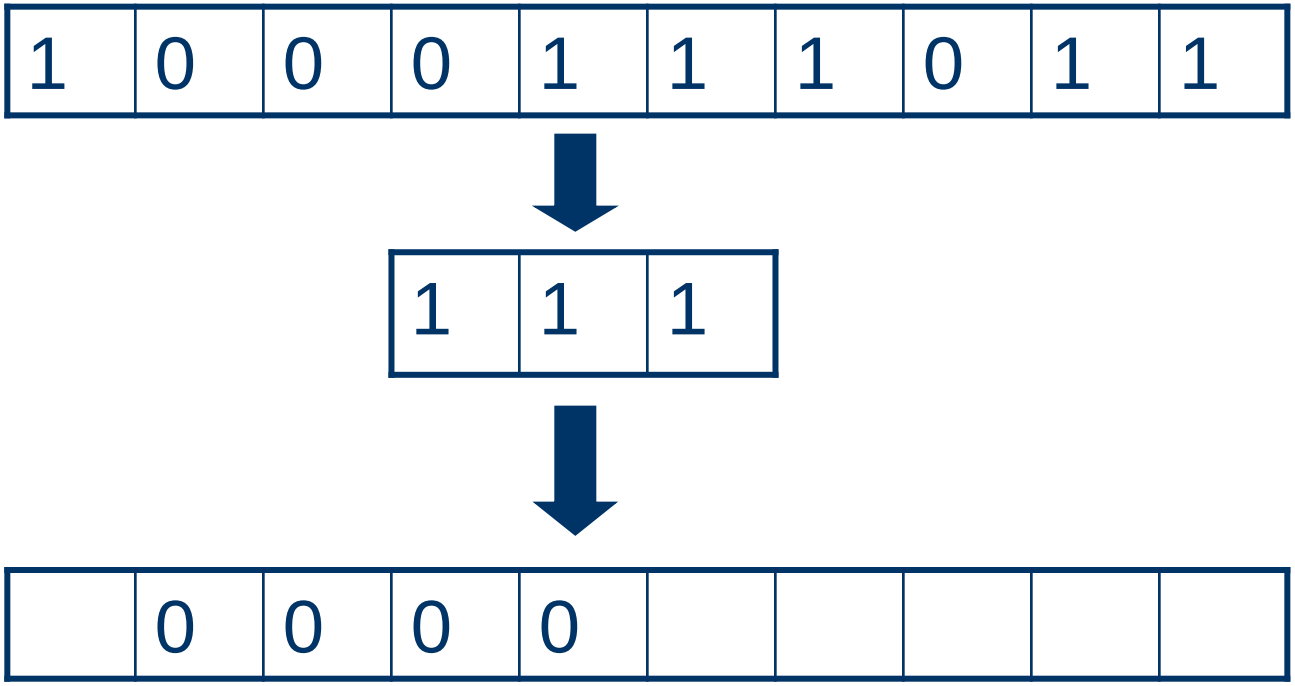
1-D Erosion example (2)



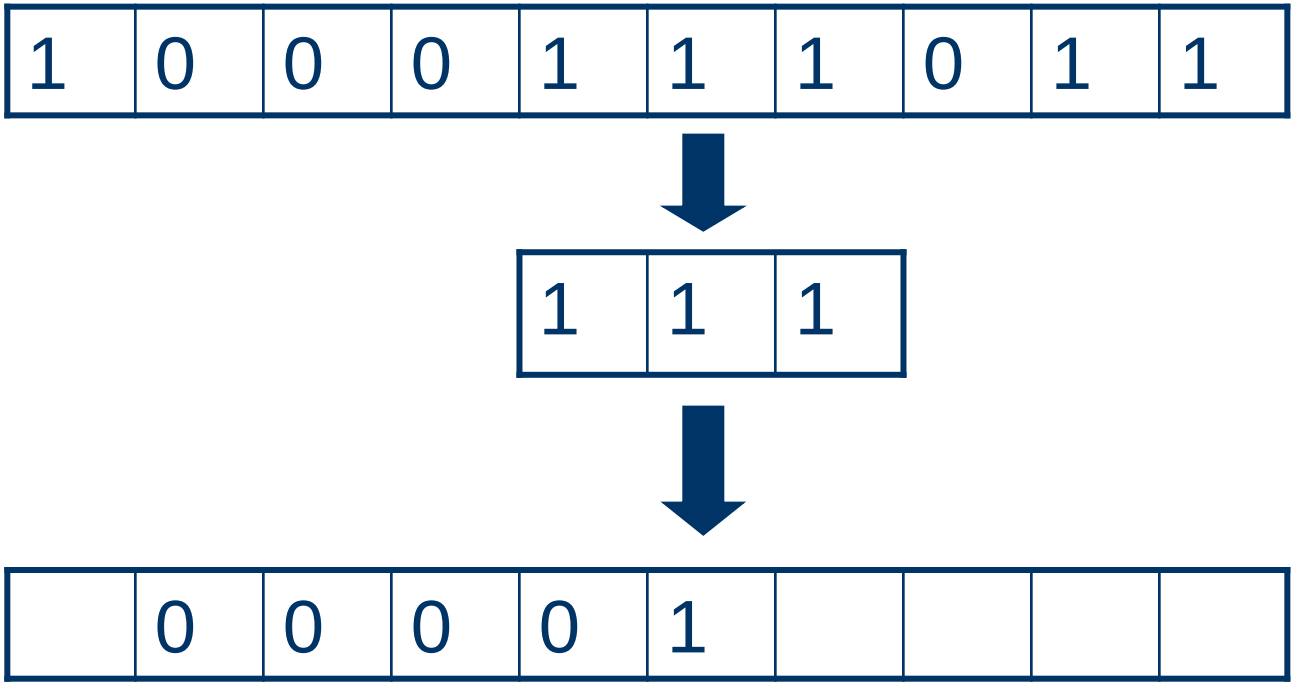
1-D Erosion example (3)



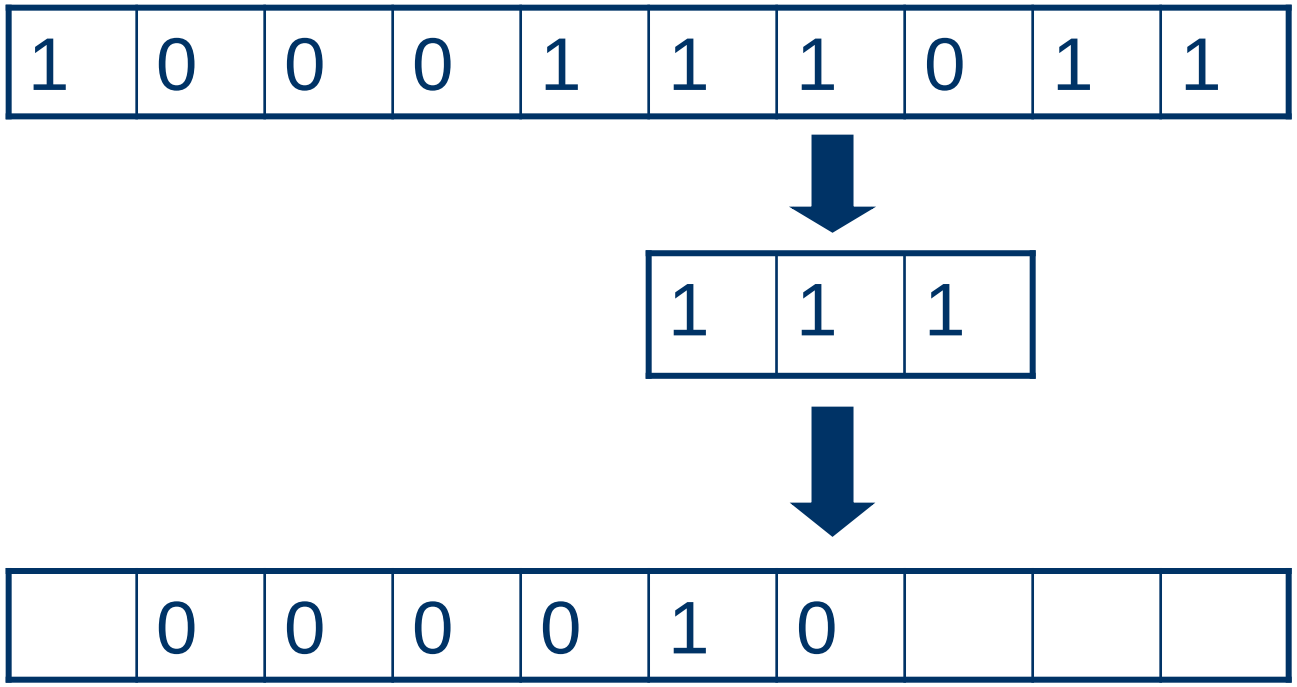
1-D Erosion example (4)



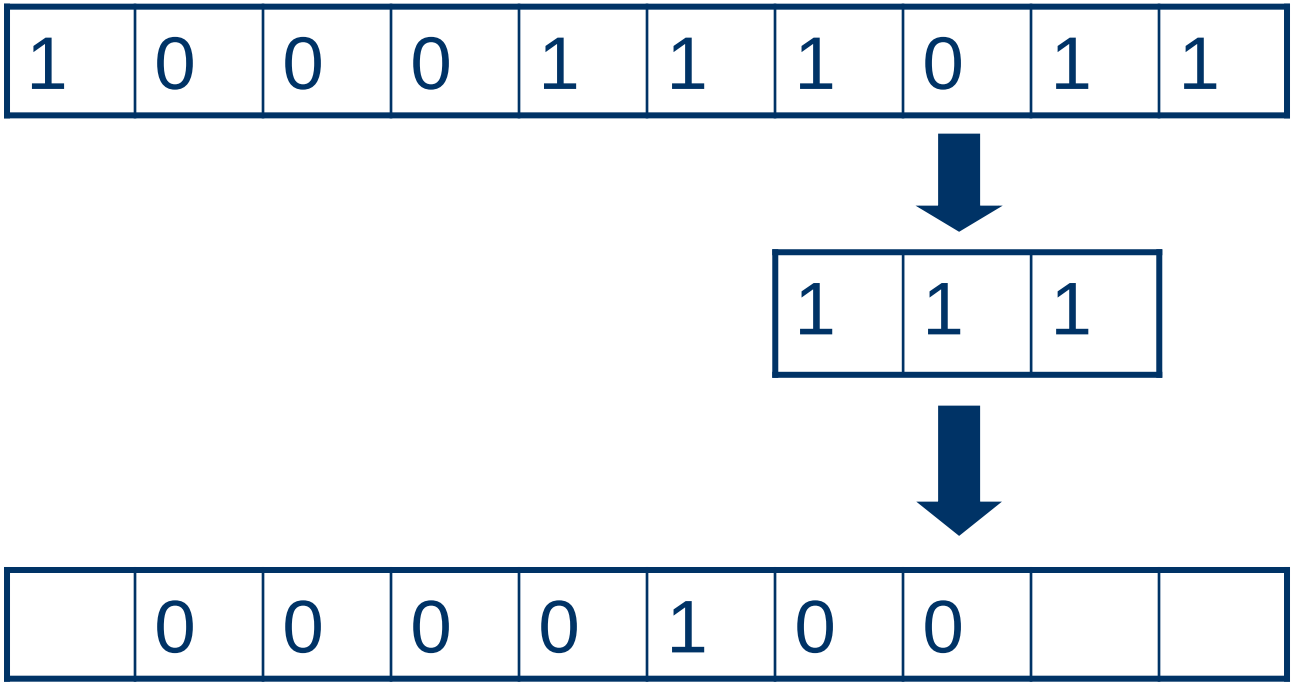
1-D Erosion example (5)



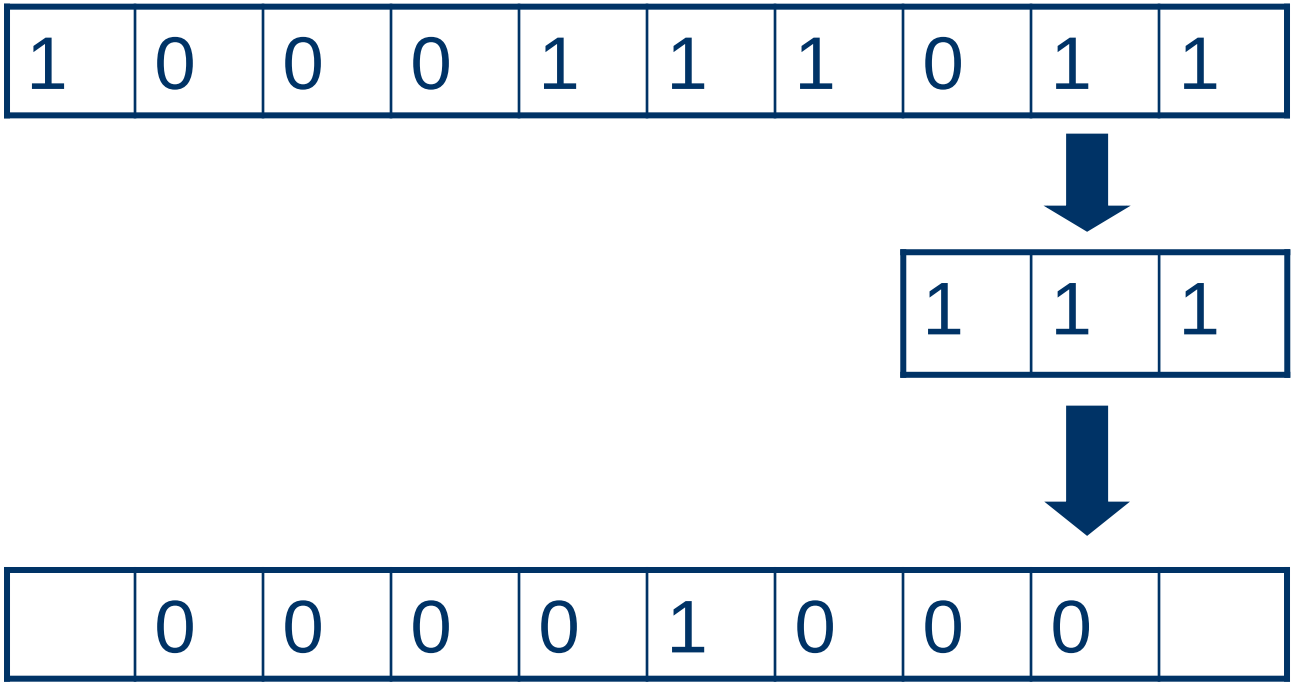
1-D Erosion example (6)



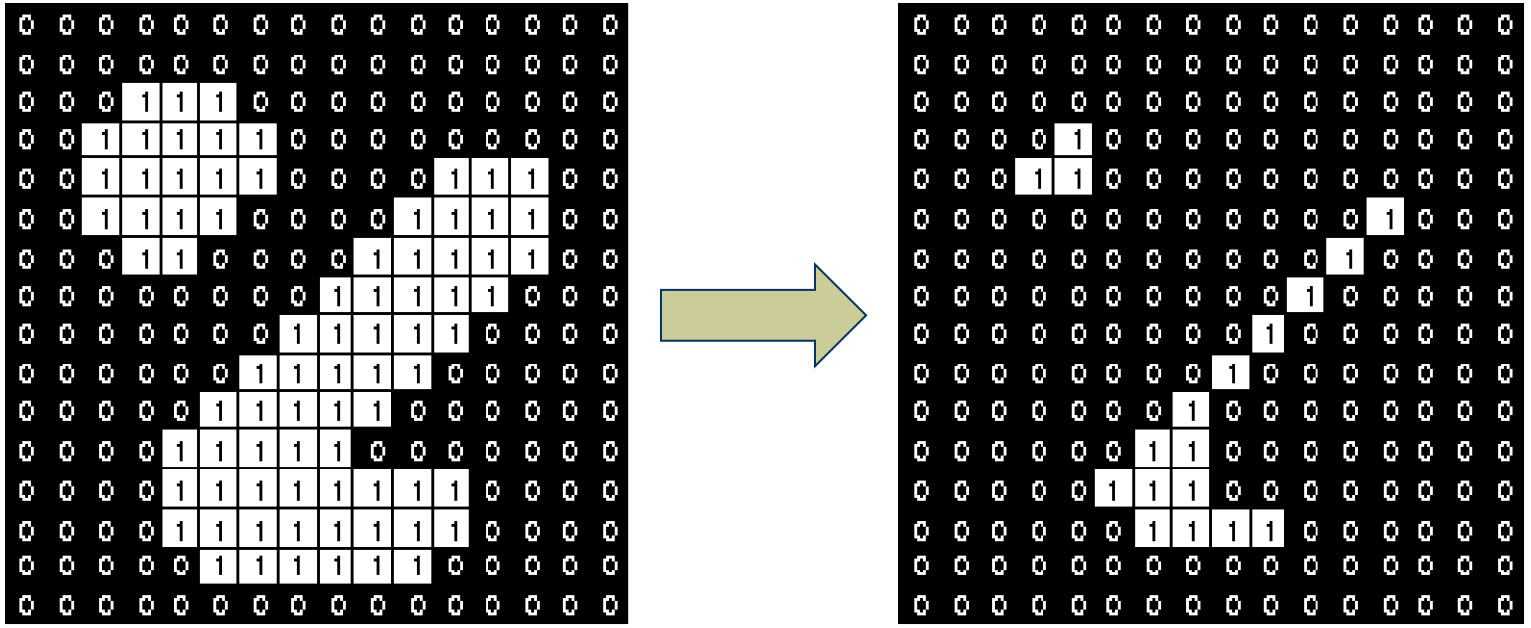
1-D Erosion example (7)



1-D Erosion example (8)

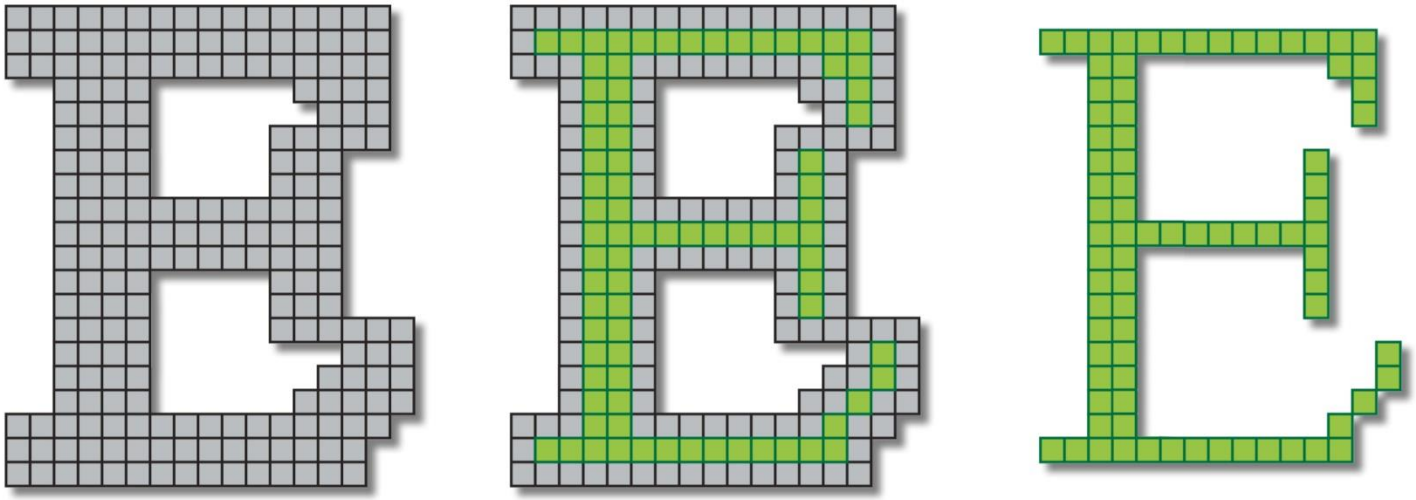


Erosion – How to compute



Erosion with a structuring element of size 3x3

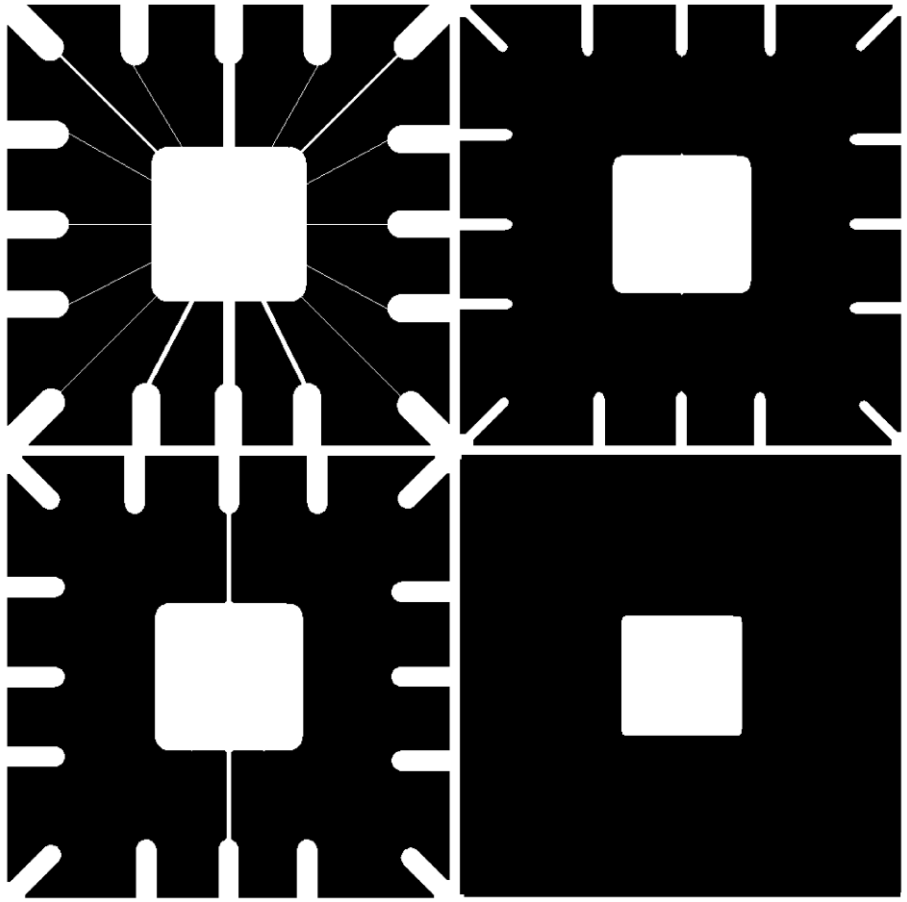
Erosion- How to compute



Erosion

- Effects
  - Shrinks the size of foreground (1-valued) objects
  - Smooths object boundaries
  - Removes small objects

Erosion: Example 1



Original image

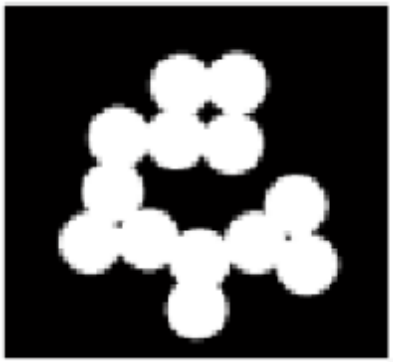
After erosion with a disc of radius 10

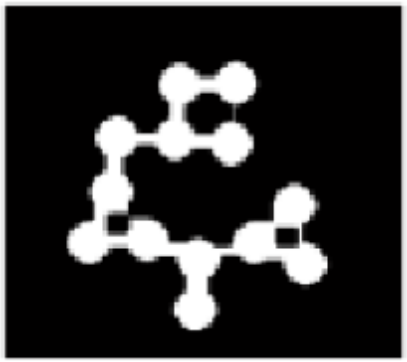
After erosion with a disc of radius 5

After erosion with a disc of radius 20

Erosion: Example 2

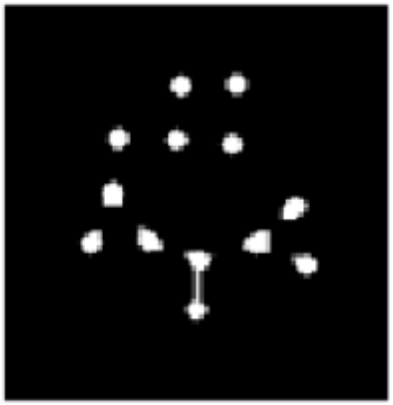
Original binary image *circles*

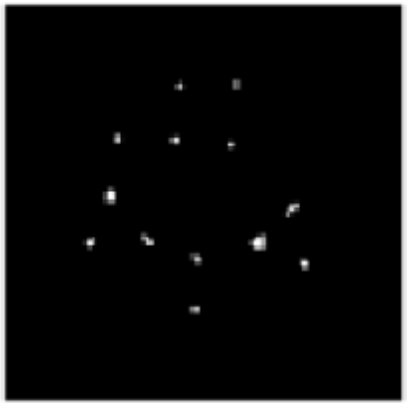




Erosion by 11x11 structuring element

Erosion by 21x21 structuring element



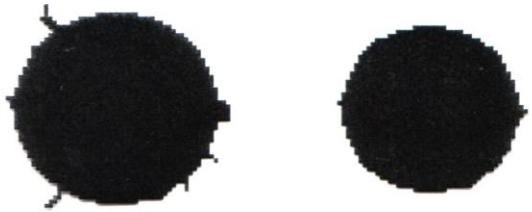


Erosion by 27x27 structuring element

Erosion

Erosion can split apart joined objects

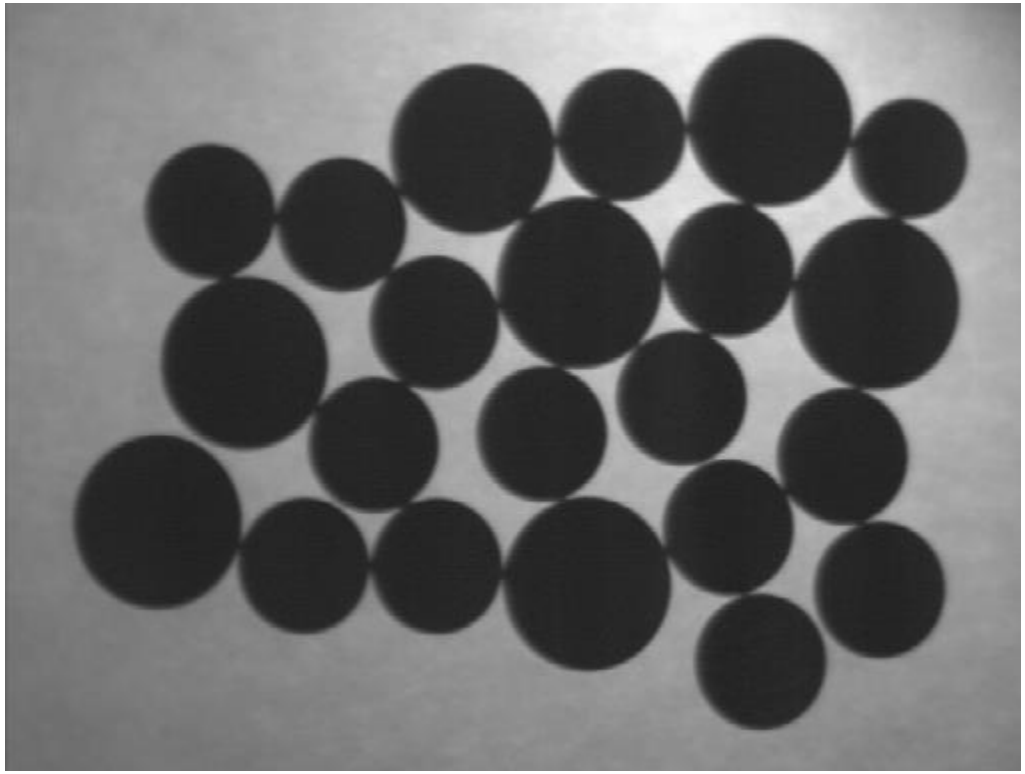
Erosion can strip away extrusions



Watch out: Erosion shrinks objects

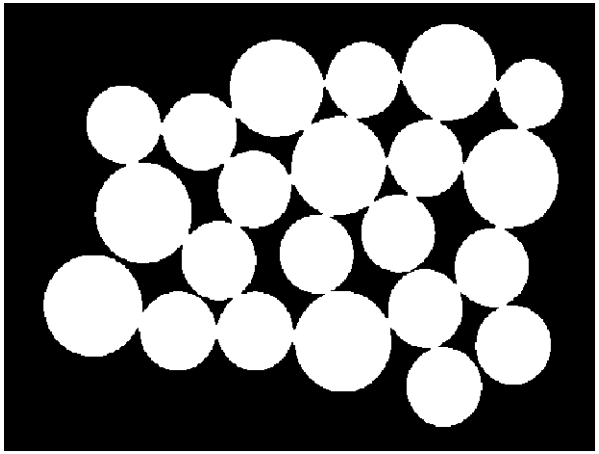
Exercise

Count the number of coins in the given image

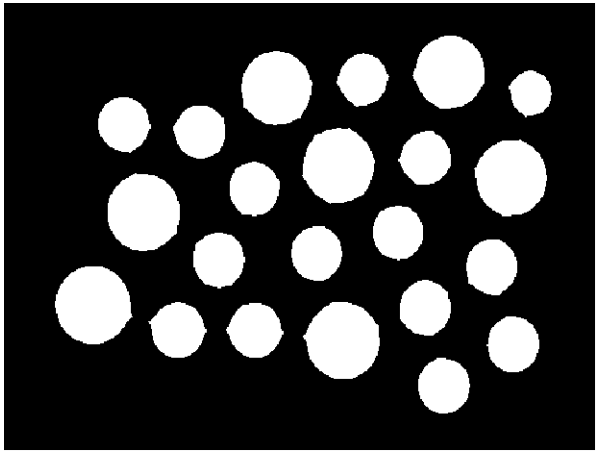


Exercise: Solution

Binarize the image



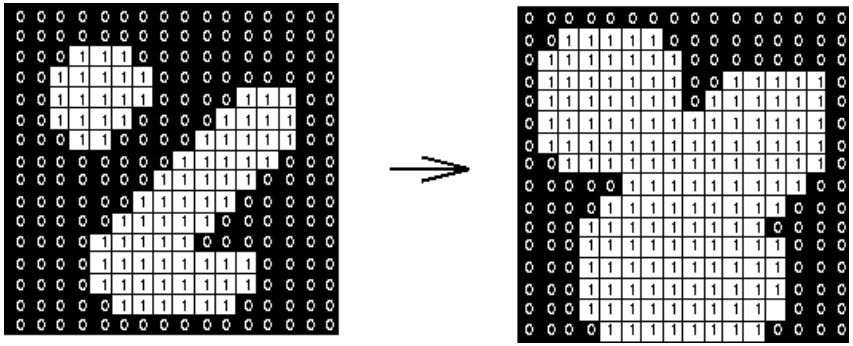
Perform Erosion



Use connected component labeling to count the number of coins:
Do in the Lab cv2.connectedComponentsWithStatsWithAlgorithm

Dilation: !! تمدد

- **Dilation** has the opposite effect of erosion.
- It ‘grows’ or ‘thickens’ objects in a binary image.
- As in erosion, this is controlled by the structuring element.



1	1	1
1	1	1
1	1	1

Set of coordinate points =

{ (-1, -1), (0, -1), (1, -1),

(-1, 0), (0, 0), (1, 0),

(-1, 1), (0, 1), (1, 1) }

Dilation

- The dilation of an image f by a structuring element s (denoted f $\oplus$ s) produces a new binary image g = f $\oplus$ s with ones in all locations *(x, y)* of a structuring element's origin at which that structuring element s *hits* the input image f in at least one location.
- The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

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

1-D Dilation Example

Input image

Structuring Element

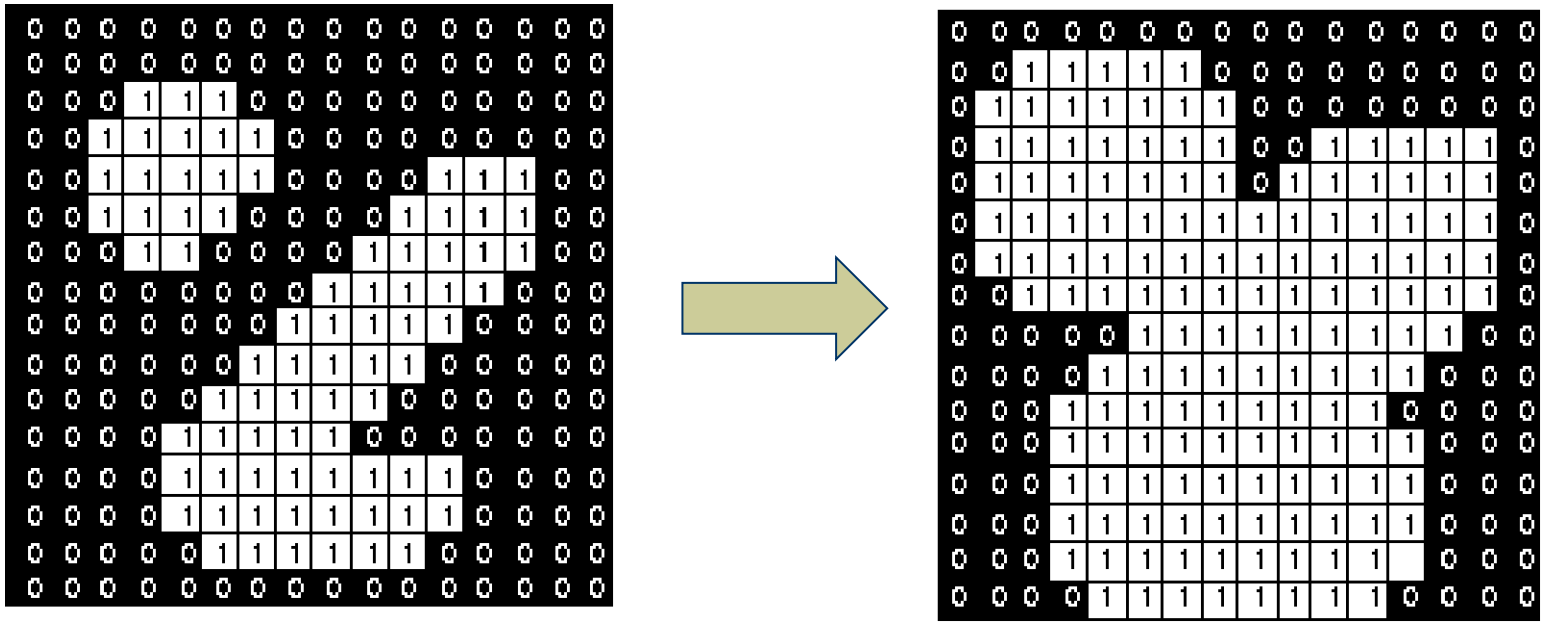
Output Image

Solution:

Dilation

- Effects
  - Expands the size of foreground objects
  - Smoothing object boundaries
  - Closes holes and gaps

Dilation: Example



Effect of dilation using a 3×3 square structuring element

Dilation: Example 1

Original image

Dilation by 3*3 square structuring element

Dilation by 5*5 square structuring element

Note: In these examples a 1 refers to a black pixel!

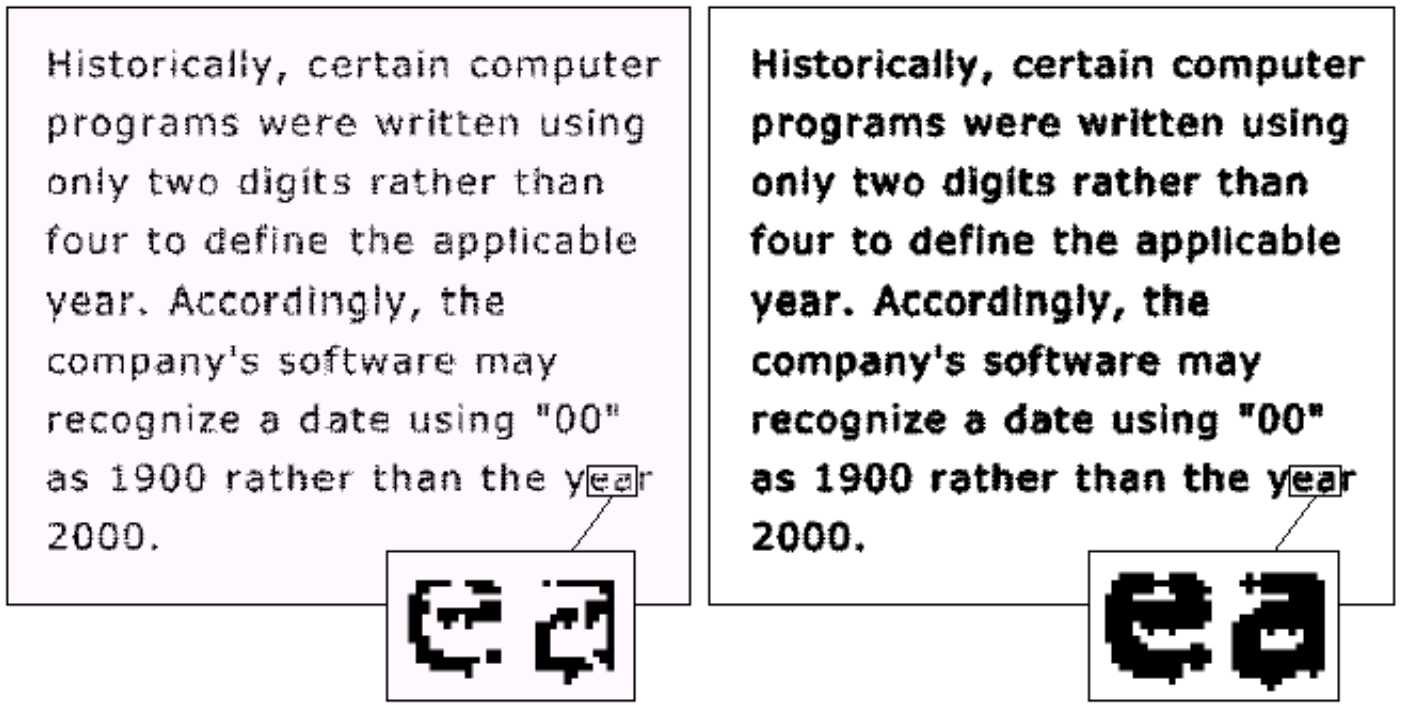
Dilation: Example 2

Original (178x178)

dilation with
3x3 structuring element

dilation with
7x7 structuring element

Dilation: Example 3



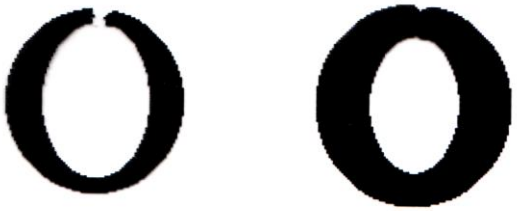
a c
b

FIGURE 9.5
(a) Sample text of poor resolution with broken characters (magnified view). (b) Structuring element. (c) Dilation of (a) by (b). Broken segments were joined.

0	1	0
1	1	1
0	1	0

Dilation

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:

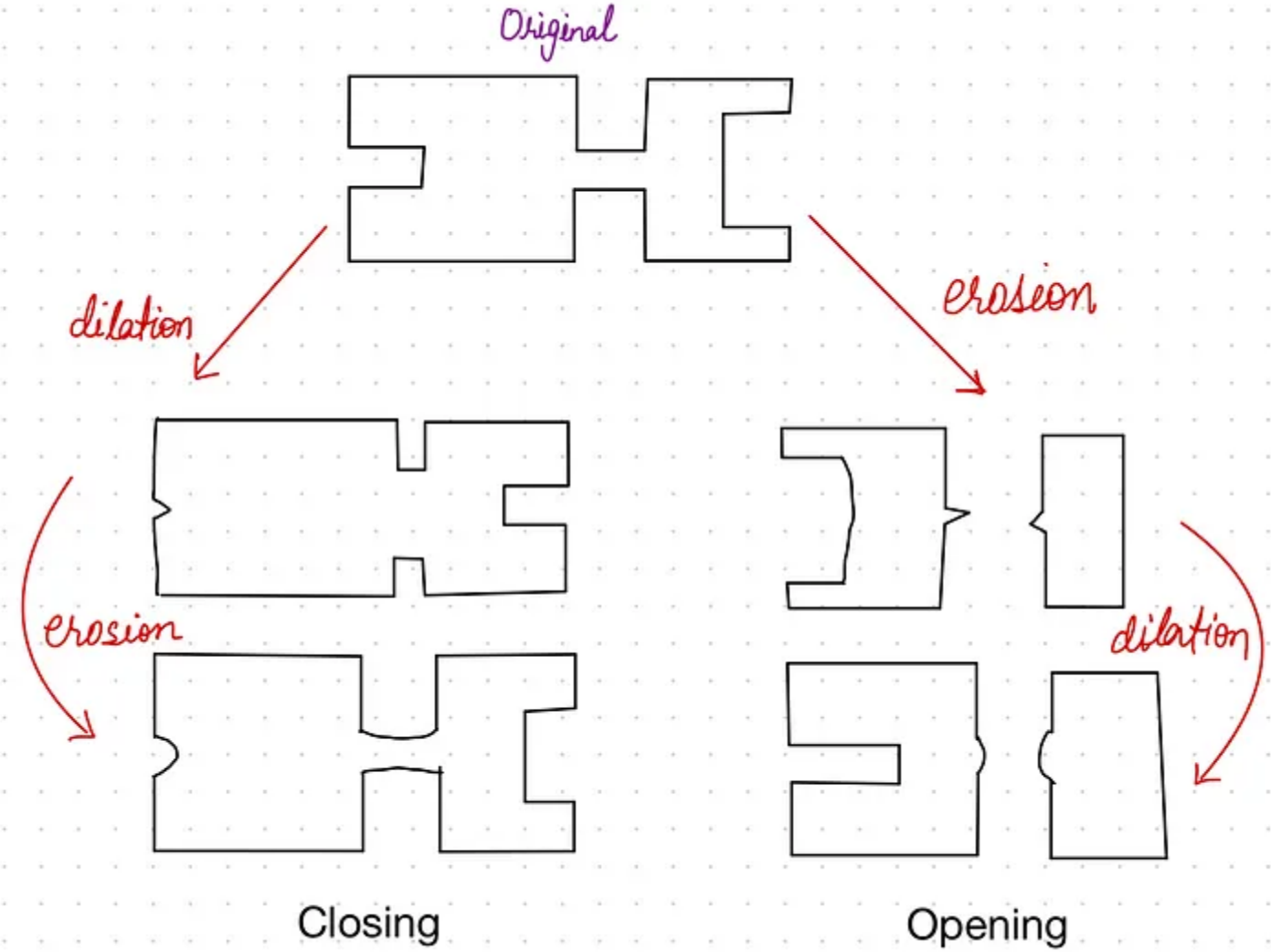
- **Opening**: *Erosion followed by Dilation*
- **Closing**: *Dilation followed by Erosion*

Opening and Closing

- Derived from the fundamental operations of Dilatation and Erosion.
- Opening and closing are dual operations (the closing of X corresponds to the opening of X^c
- **Opening and Closing are idempotent: repeated application has no further effects.**

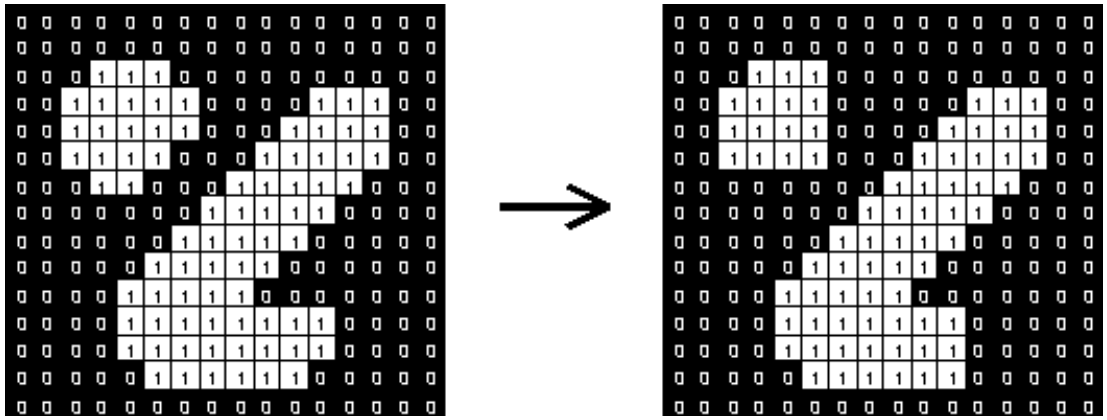
Opening:

- Similar to Erosion.
- Used mainly for **spot and noise removal**.
- However, it is **less destructive** than erosion.
- Opening is defined as an **Erosion, followed by a Dilatation** using the **same structuring element** for both operations.


Original
dilation
erosion
erosion
dilation
Closing
Opening

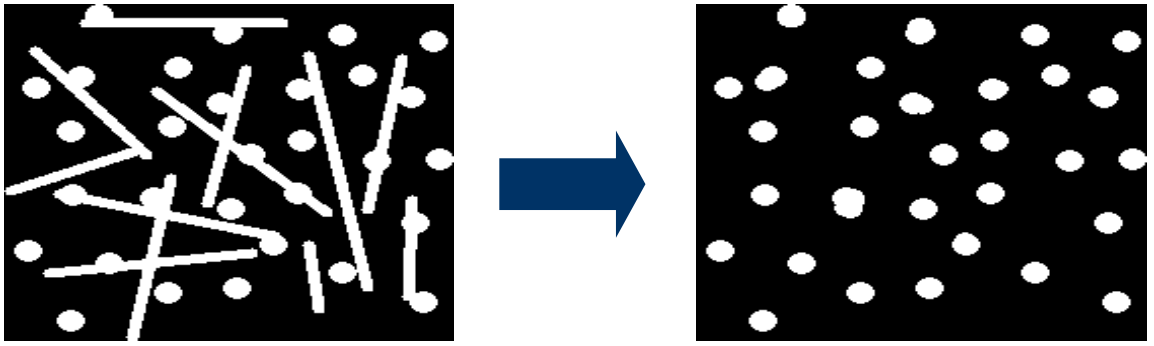
Opening

- Take the structuring element (SE) and slide it around inside each foreground region.
- All foreground pixels which can be covered by the SE with the SE being entirely within the foreground region will be preserved.
- All foreground pixels which can not be reached by the structuring element without lapping over the edge of the foreground object will be eroded away!
- **Example: Structuring element: 3x3 square**

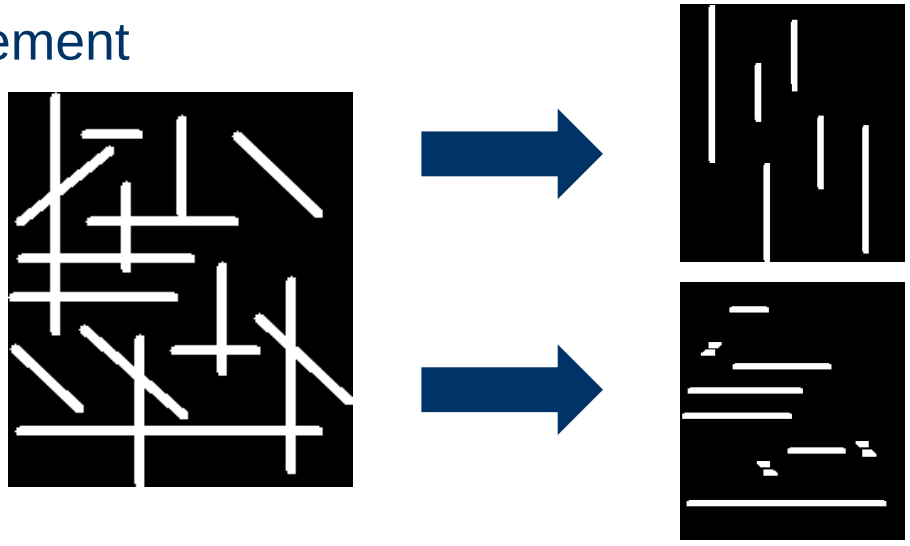


Opening examples

Opening with a 11 pixel diameter disc:



3x9 and 9x3 Structuring Element



So it can be used to search for a specific shape: e.g. Car Plate

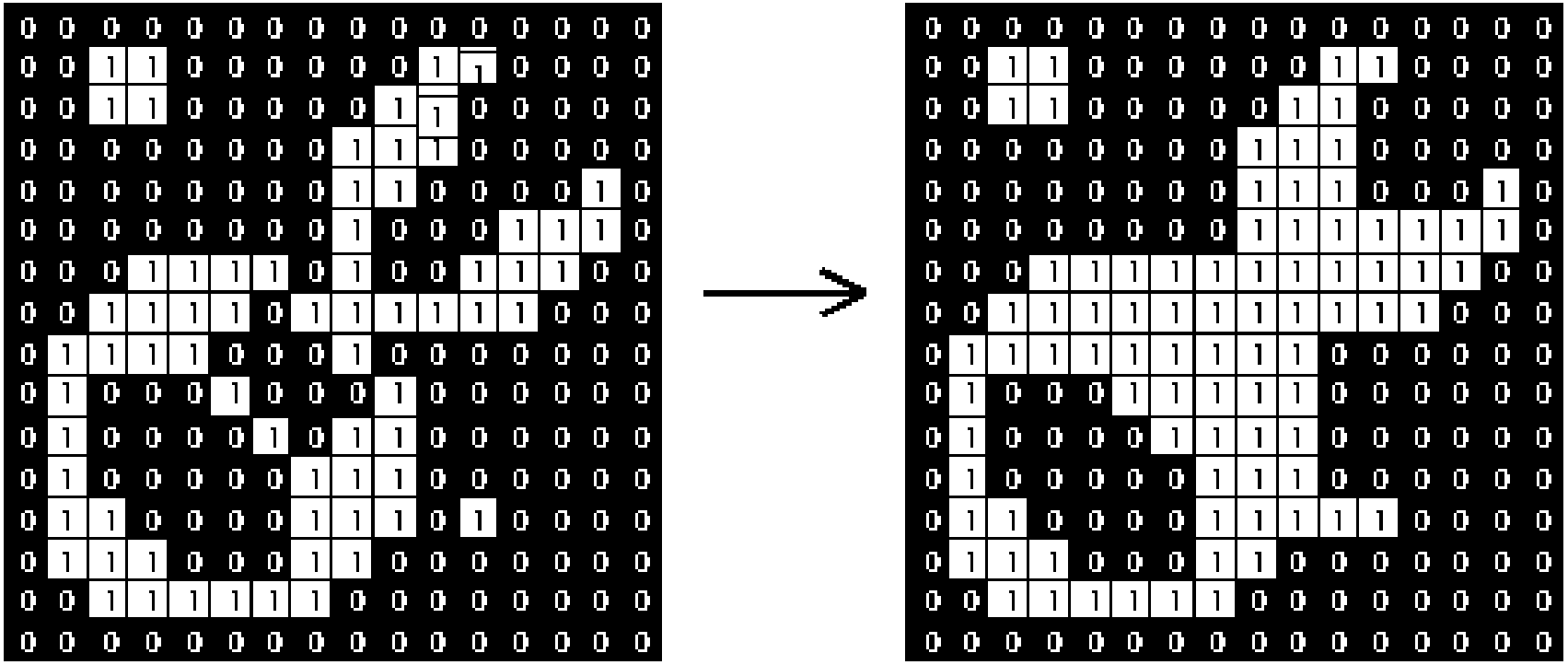
Closing

Closing:

- Similar to Dilation – used for **removal of holes** and **region filling**
- Closing is defined as a **Dilatation, followed by an Erosion** using the **same structuring element** for both operations.
- Take the structuring element (SE) and slide it around outside each foreground region.
- All background pixels which can be covered by the SE with the SE being entirely within the background region will be preserved.
- All background pixels which can not be reached by the structuring element without lapping over the edge of the foreground object will be turned into a foreground.

Closing example

Example: structuring element: 3x3 square

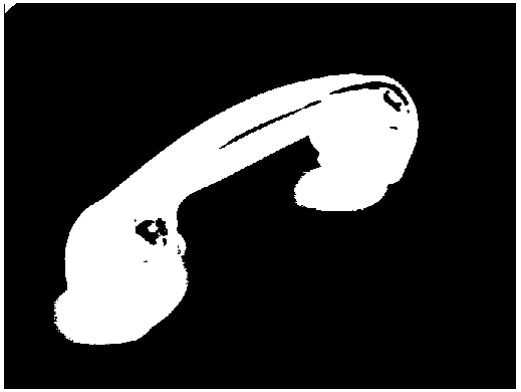
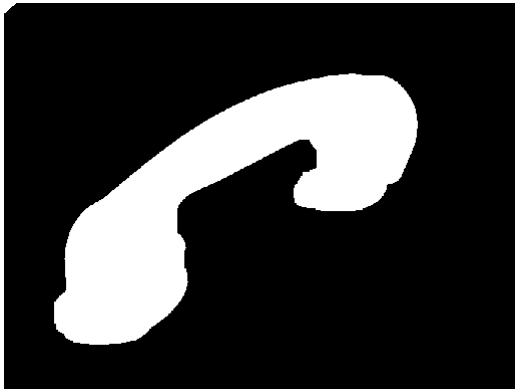


Another closing example

Closing operation with a 22 pixel disc, closes small holes in the foreground.

And another…

Threshold, closing with disc of size 20.

Note that opening is the **dual** of closing i.e. opening the foreground pixels with a particular structuring element is equivalent to closing the background pixels with the same element.

Opening followed by closing example

- Opening removes the noisy spots in the fingerprint image. However, numerous gaps are introduced in the ridges of the fingerprint.
- These are filled in by the closing operation

a b c

FIGURE 9.11 (a) Noisy fingerprint image. (b) Opening of image. (c) Opening followed by closing. (Original image courtesy of the National Institute of Standards and Technology.)