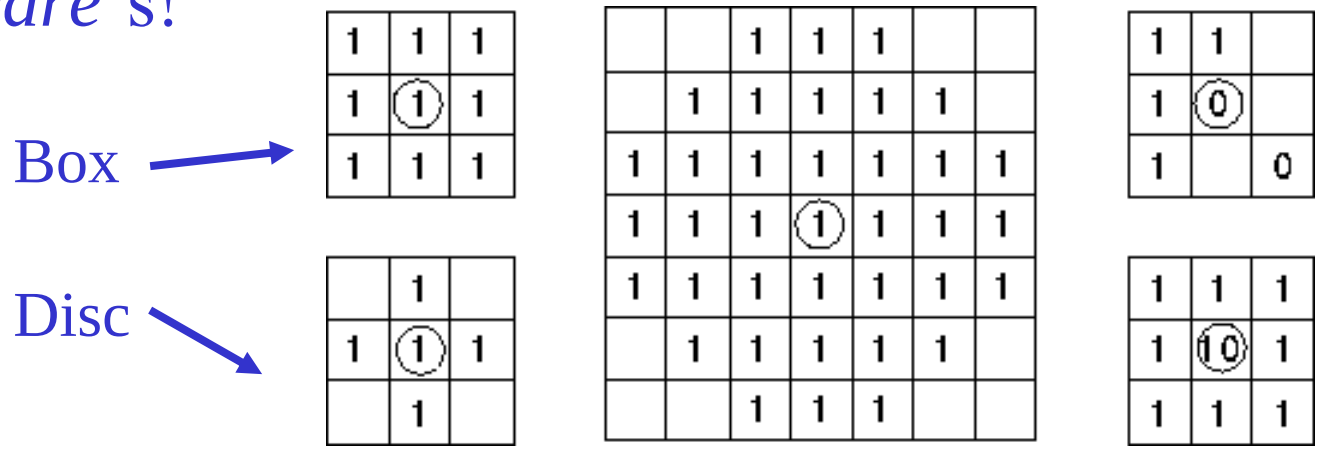
Introduction to Morphological Operators

Introduction

- Structuring Element
- Erosion
- Dilation
- Opening
- Closing

Structuring Element (Kernel)

- Structuring Elements can have varying sizes
- Usually, element values are 0,1 and none(!)
- Structural Elements have an origin
- For thinning, other values are possible
- Empty spots in the Structuring Elements are *don't care*'s!



Examples of stucturing elements

Dilation & Erosion

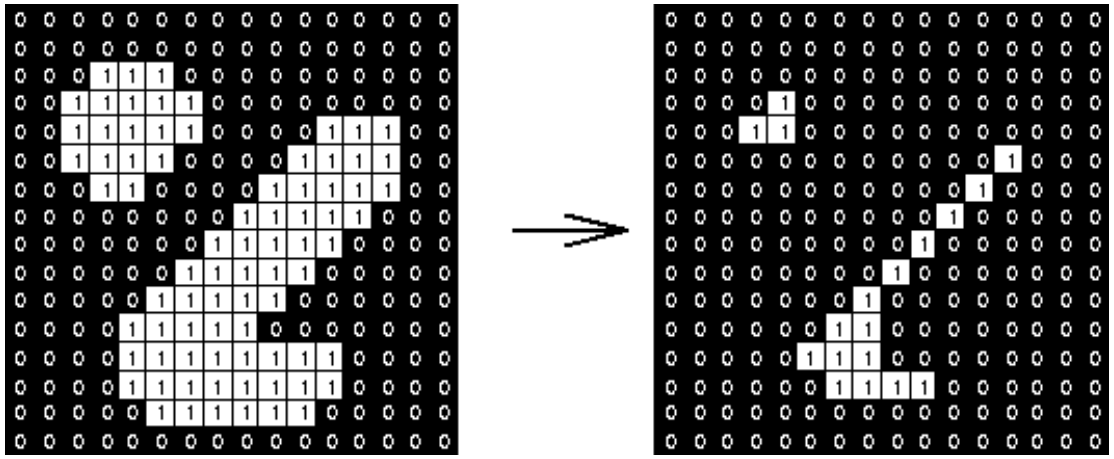
- Basic operations
- Are dual to each other:
  - Erosion shrinks foreground, enlarges Background
  - Dilation enlarges foreground, shrinks background

Erosion

- **Erosion** is the set of all points in the image, where the structuring element “fits into”.
- Consider each foreground pixel in the input image
  - If the structuring element fits in, write a “1” at the origin of the structuring element!
- Simple application of **pattern matching**
- **Input:**
  - **Binary Image (Gray value)**
  - **Structuring Element, containing only 1s!**

A first Example: Erosion

- **Erosion** is an important morphological operation



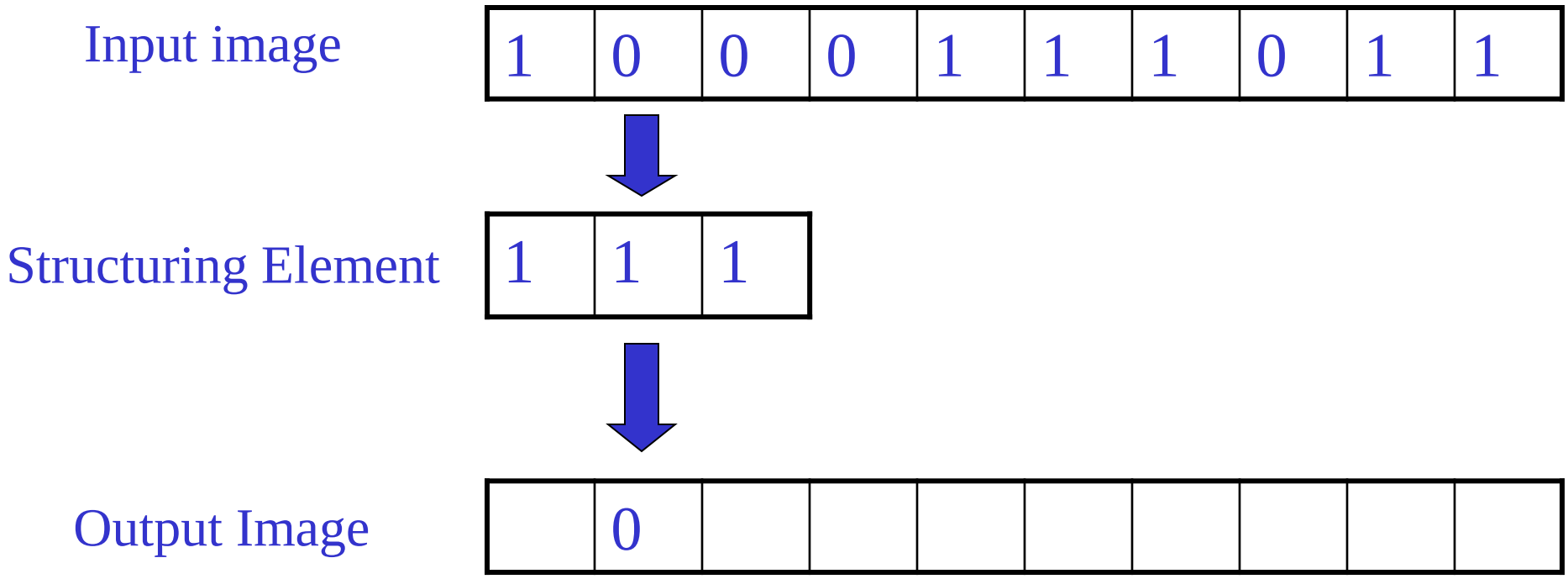
- Applied **Structuring Element**:

1	1	1
1	1	1
1	1	1

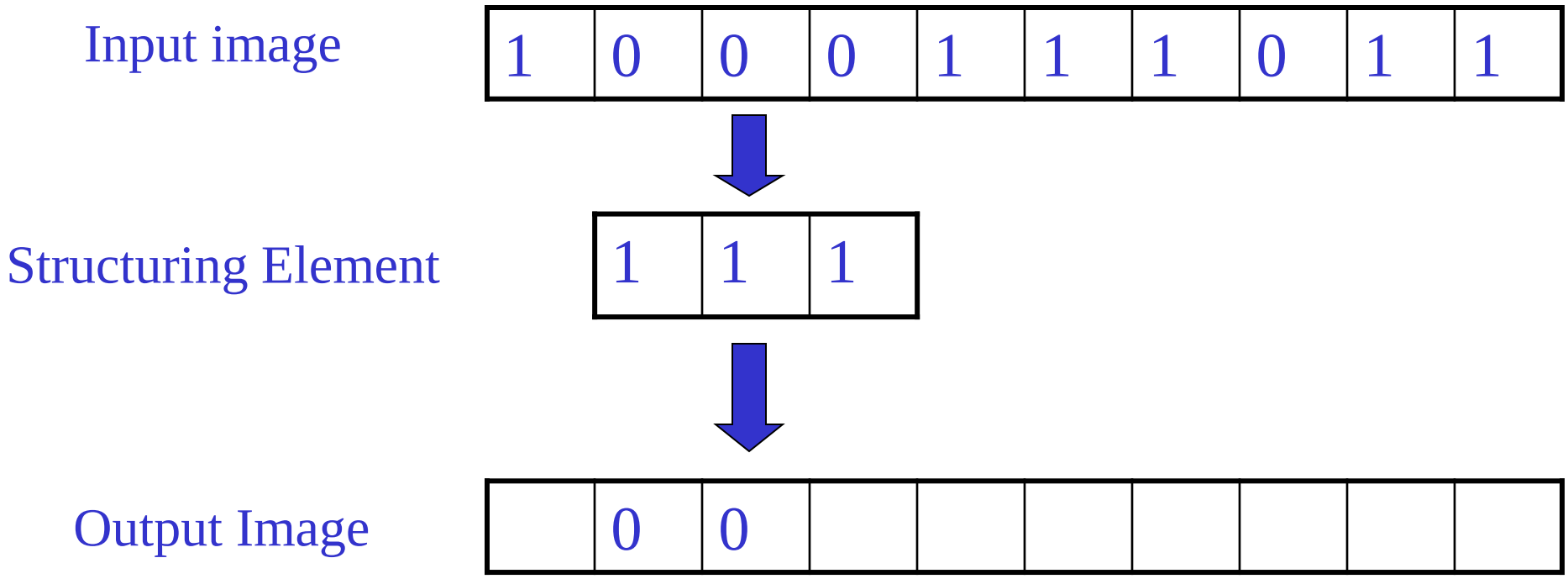
Set of coordinate points =

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

Example for Erosion

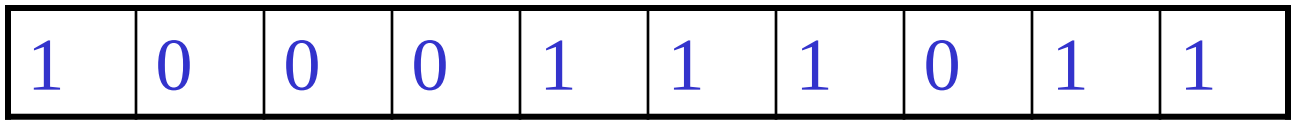


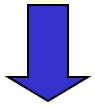
Example for Erosion



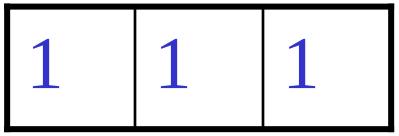
Example for Erosion

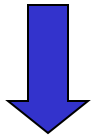
Input image



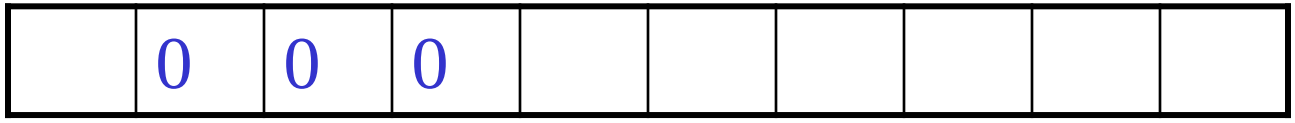


Structuring Element



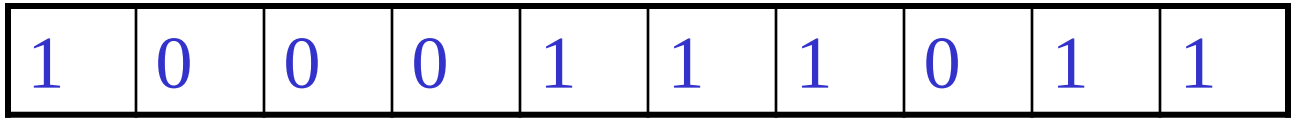


Output Image

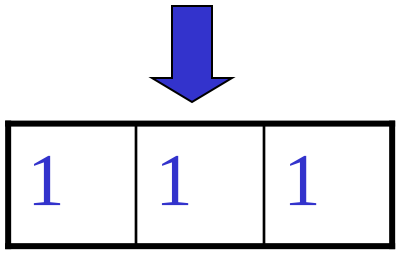


Example for Erosion

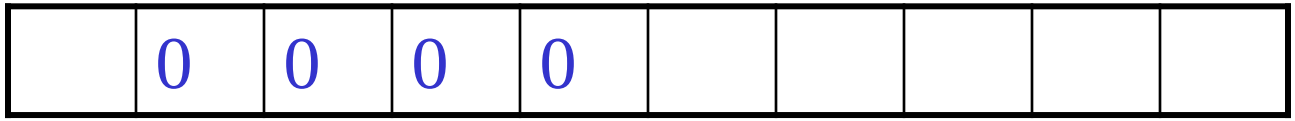
Input image



Structuring Element

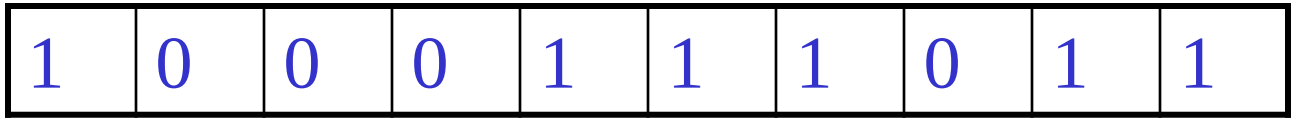


Output Image

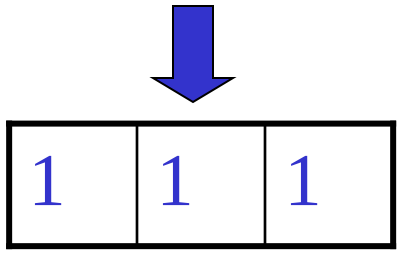


Example for Erosion

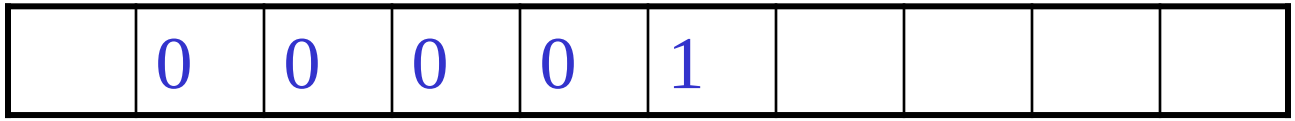
Input image



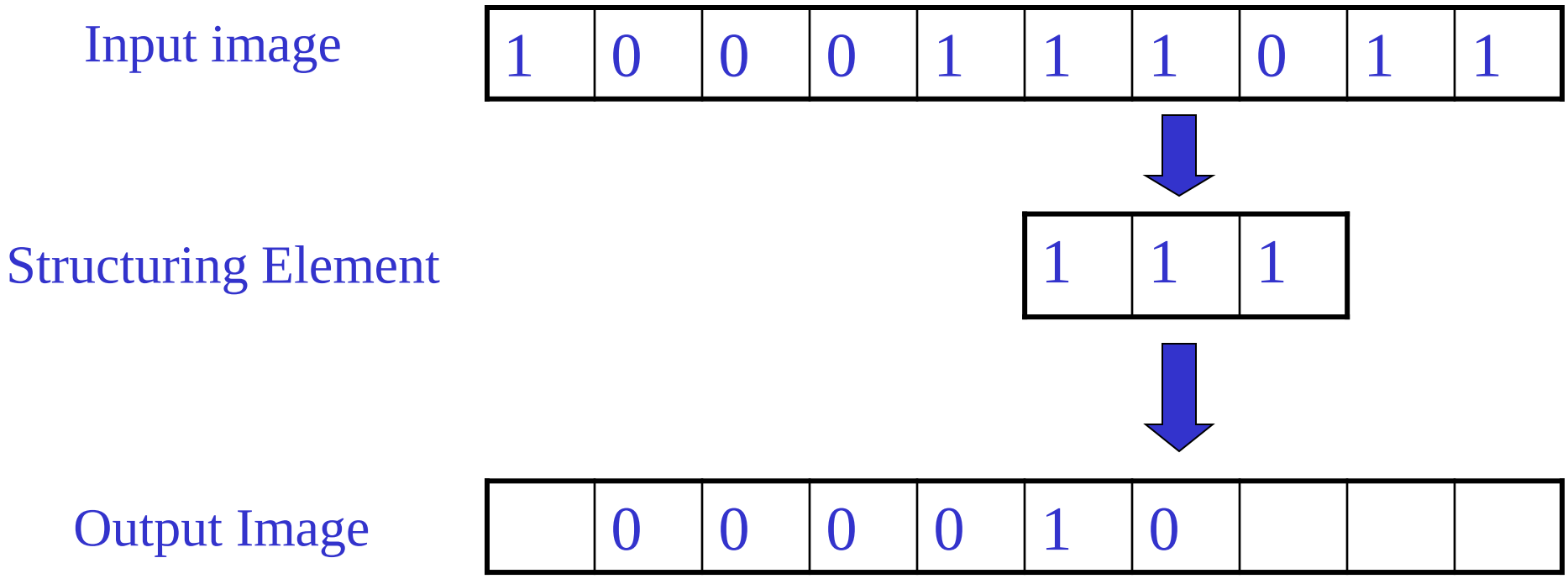
Structuring Element



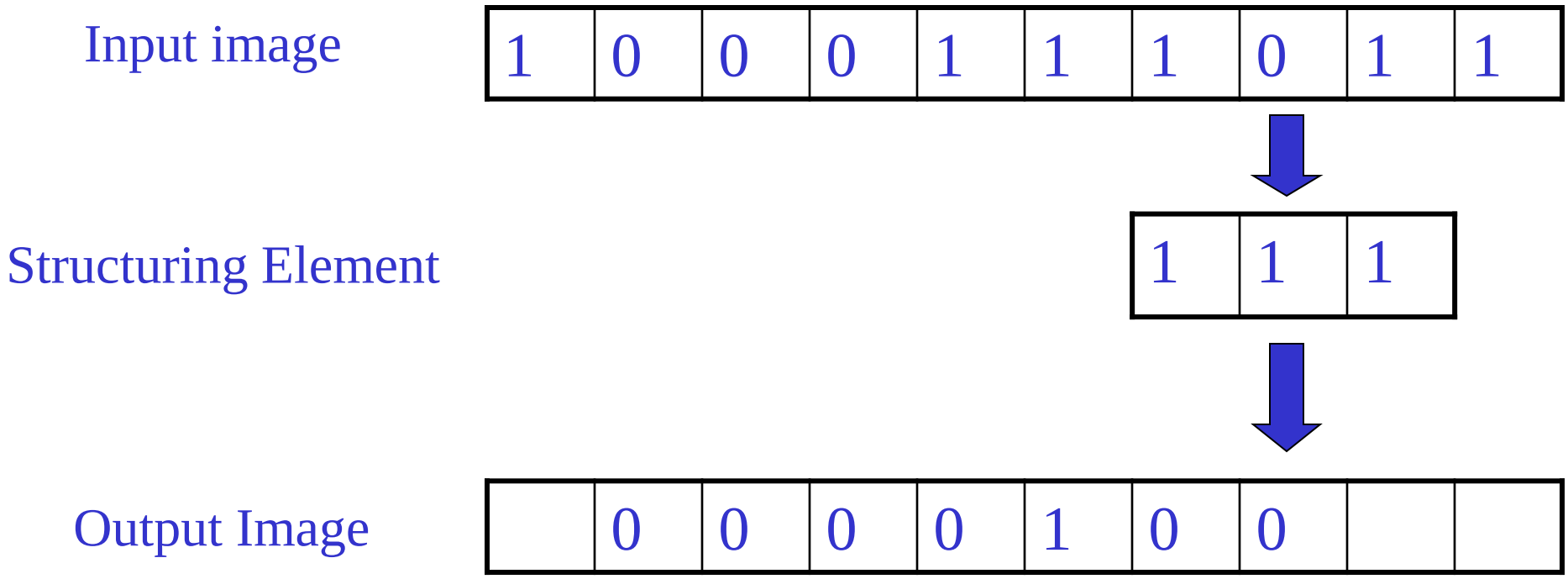
Output Image



Example for Erosion

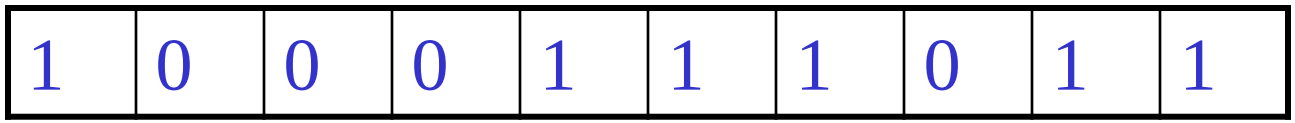


Example for Erosion

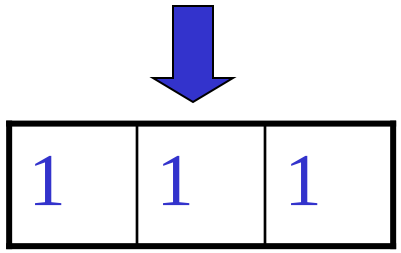


Example for Erosion

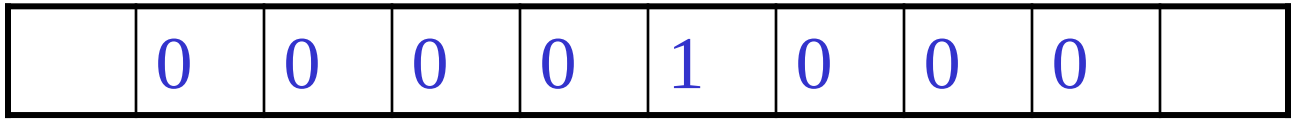
Input image



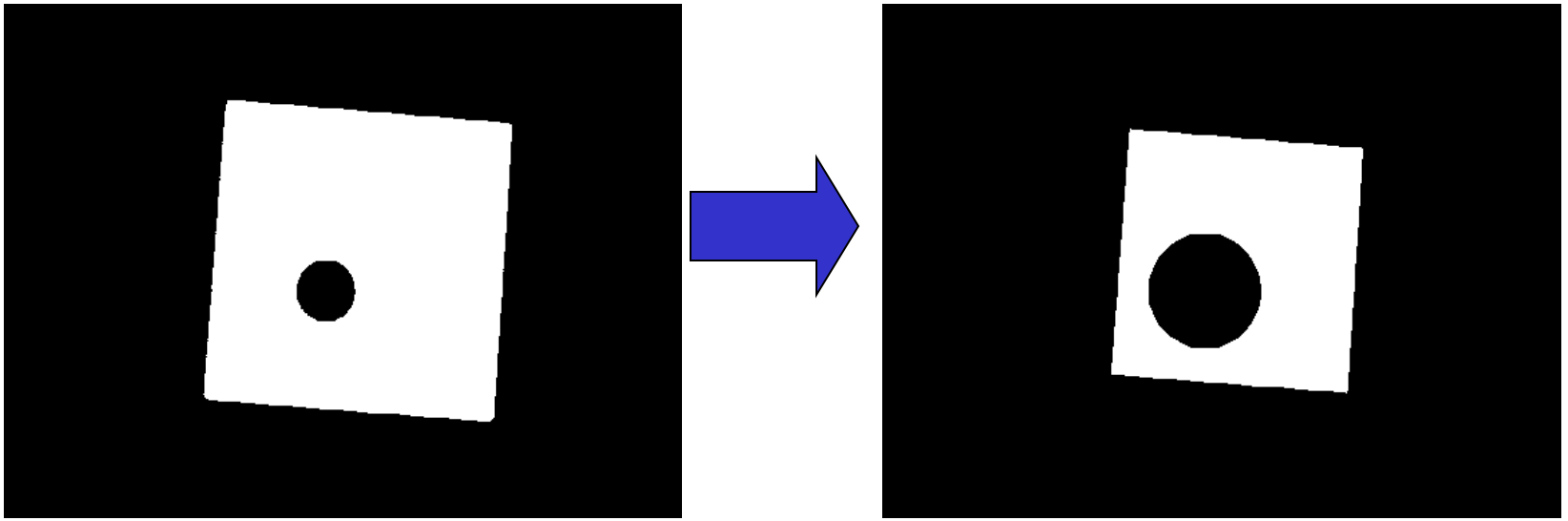
Structuring Element



Output Image



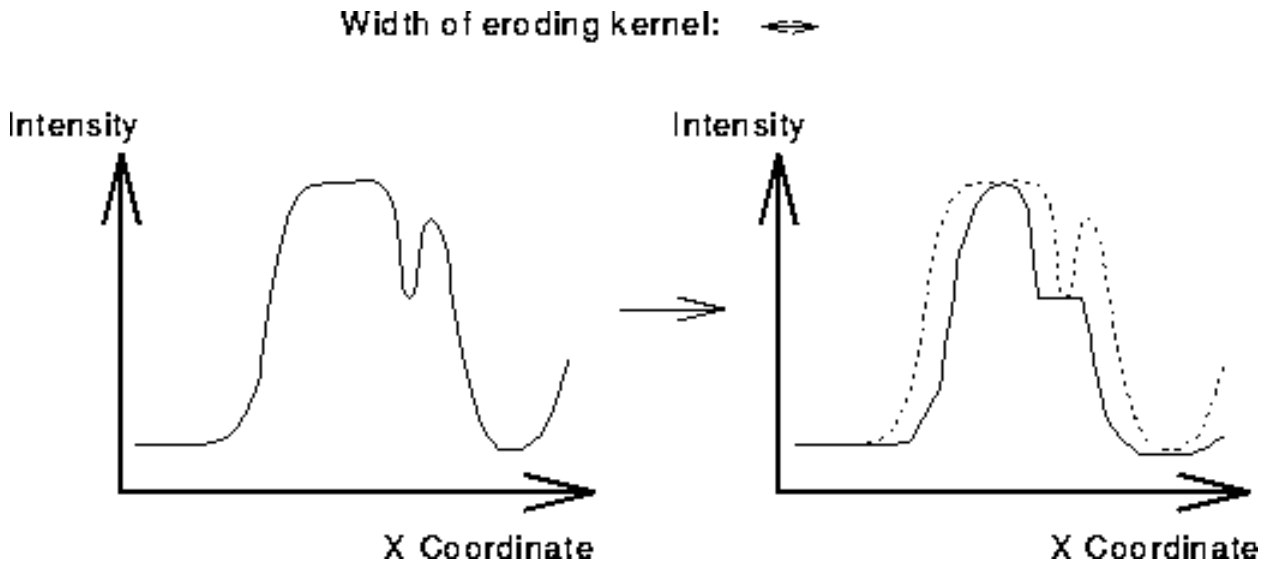
Another example of erosion



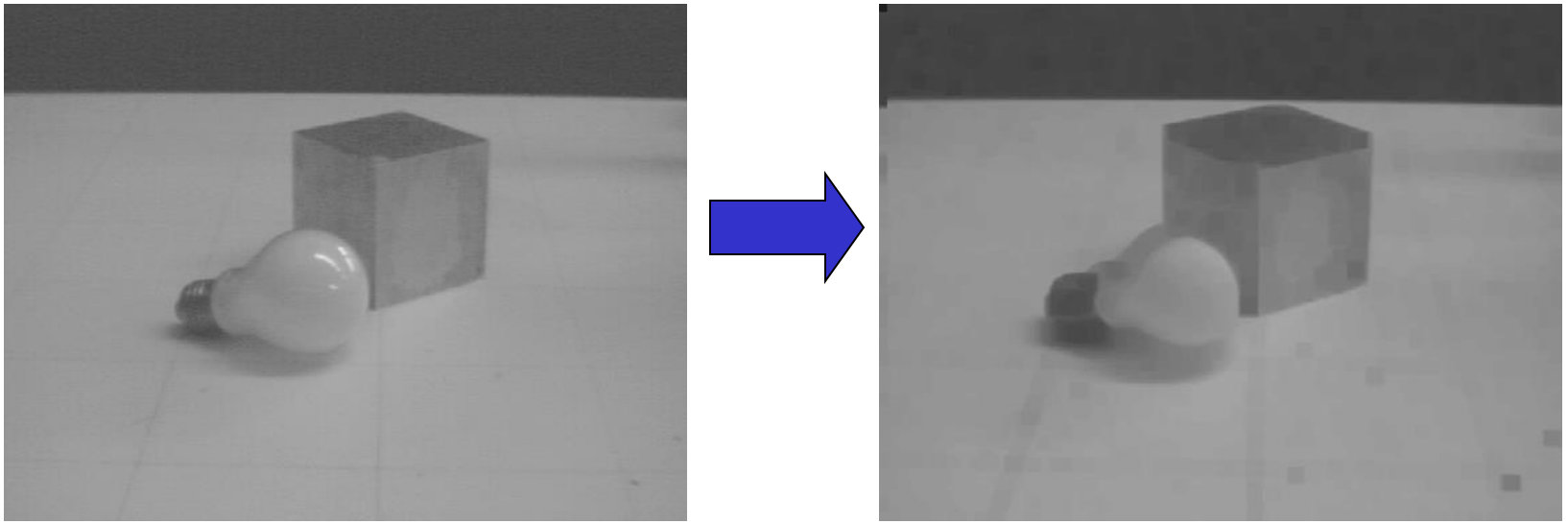
- White = 0, black = 1, dual property, image as a result of erosion gets darker

Erosion on Gray Value Images

- View gray value images as a stack of binary images!



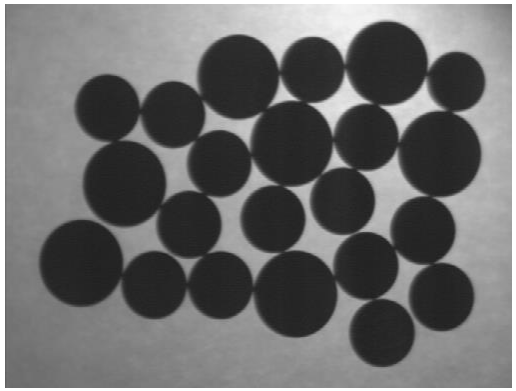
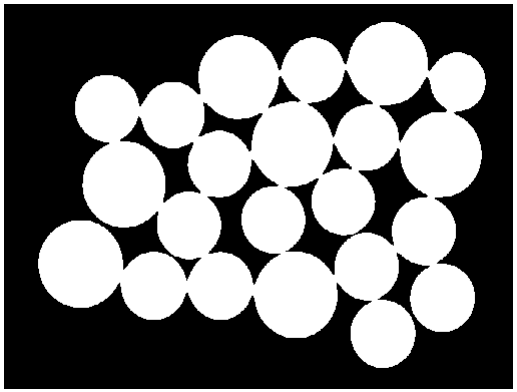
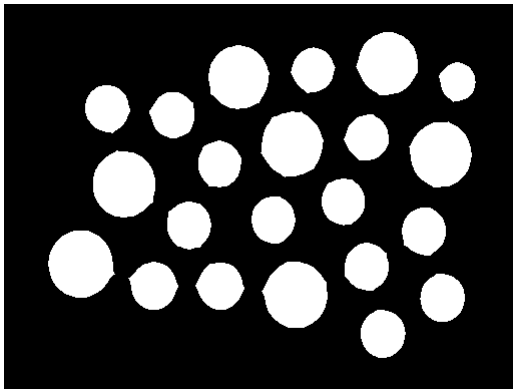
Erosion on Gray Value Images



- Images get darker!

Counting Coins

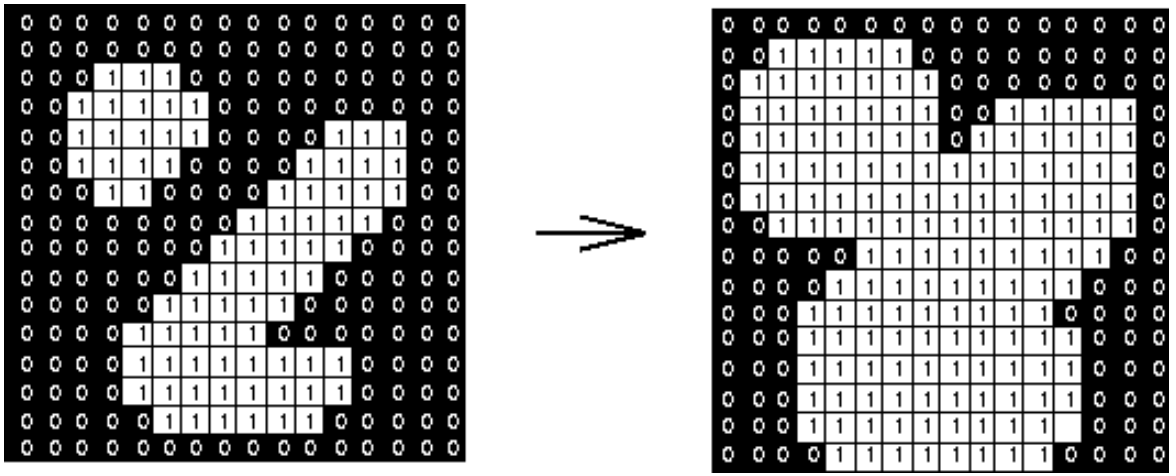
- Counting coins is difficult because they touch each other!
- Solution: Binarization and Erosion separates them!

DILATION

Example: Dilation

- **Dilation** is an important morphological operation



- Applied **Structuring Element**:

1	1	1
1	1	1
1	1	1

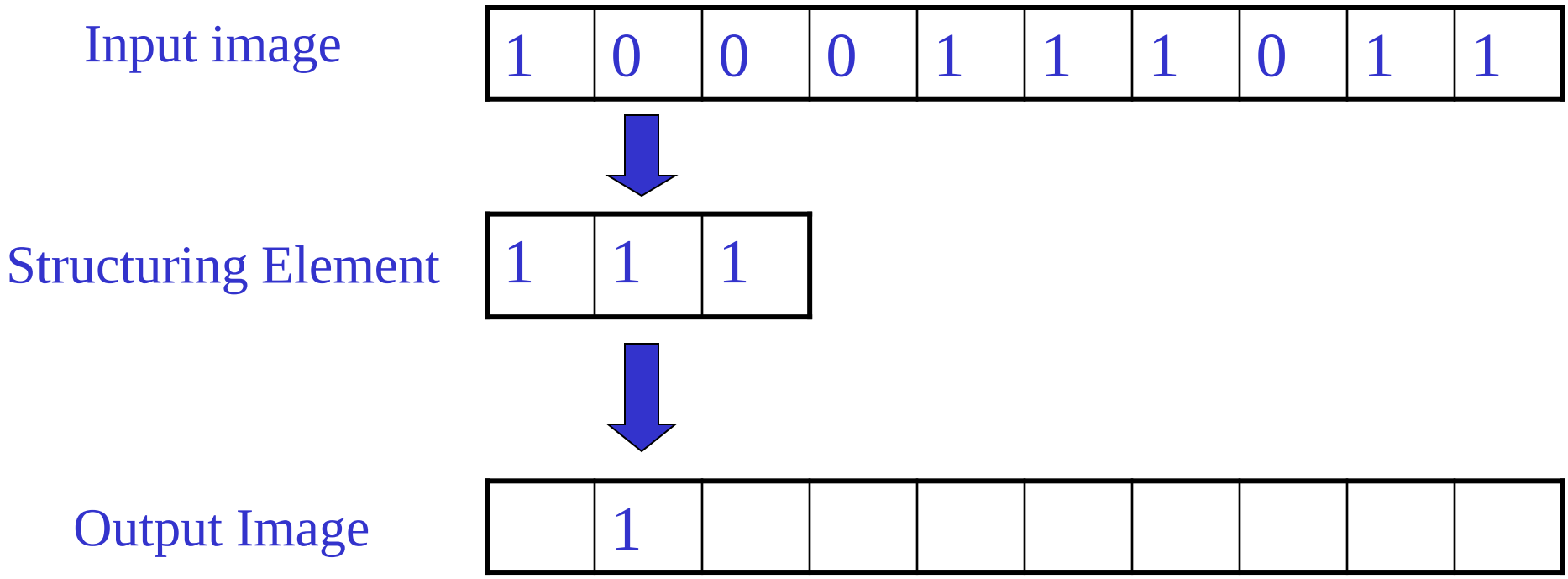
Set of coordinate points =

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

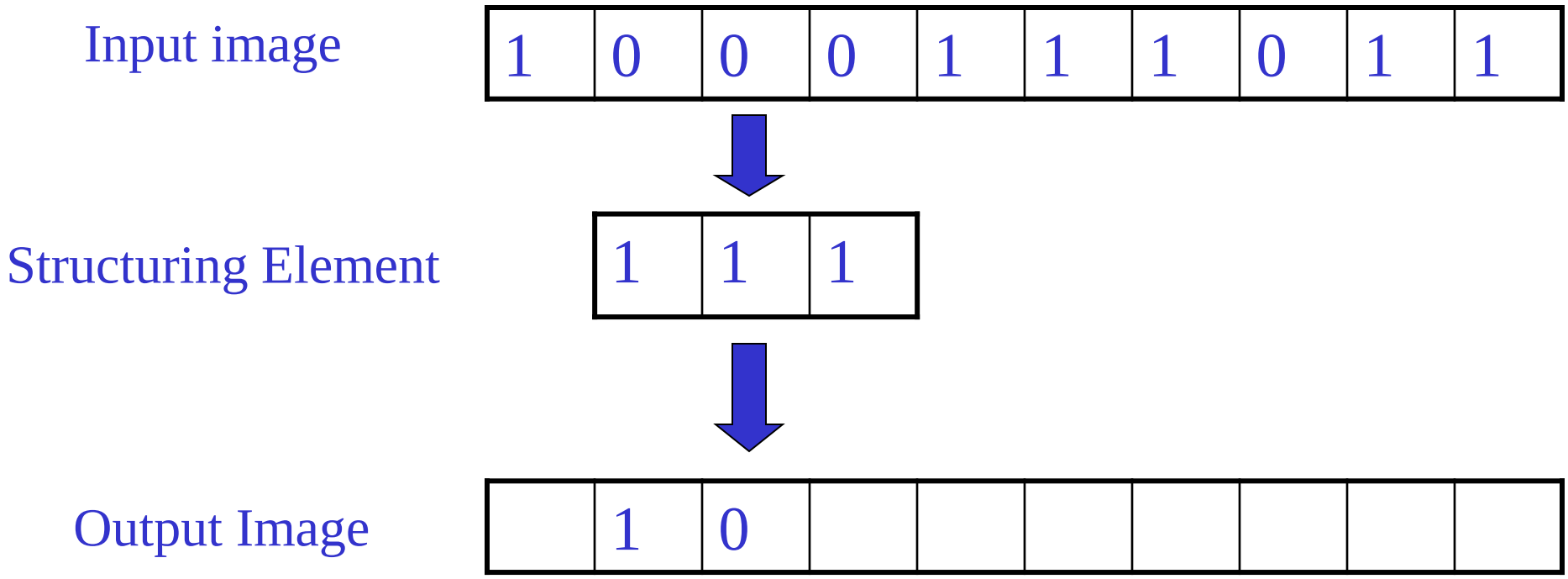
Dilation

- **Dilation** is the set of all points in the image, where the structuring element “touches” the foreground.
- Consider each pixel in the input image
  - If the structuring element touches the foreground image, write a “1” at the origin of the structuring element!
- **Input:**
  - **Binary Image**
  - **Structuring Element, containing only 1s!!**

Example for Dilation

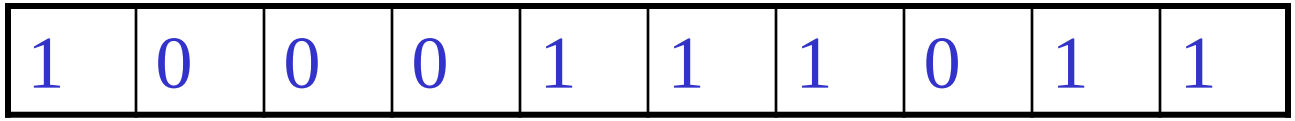


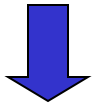
Example for Dilation



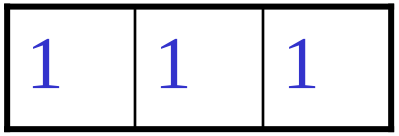
Example for Dilation

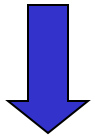
Input image



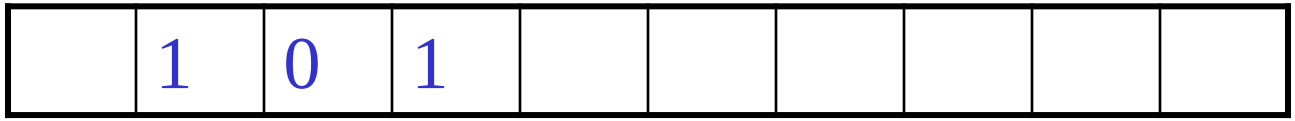


Structuring Element



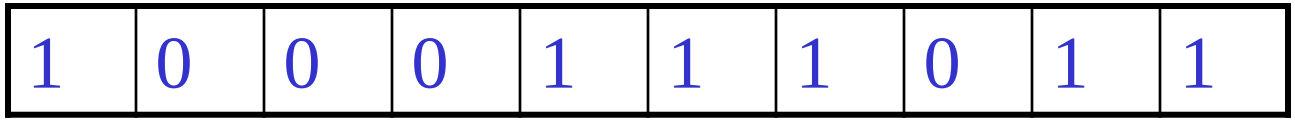


Output Image

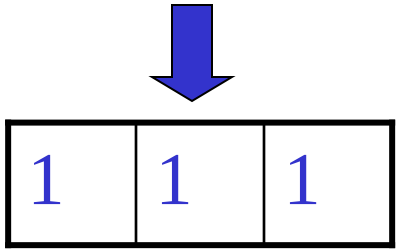


Example for Dilation

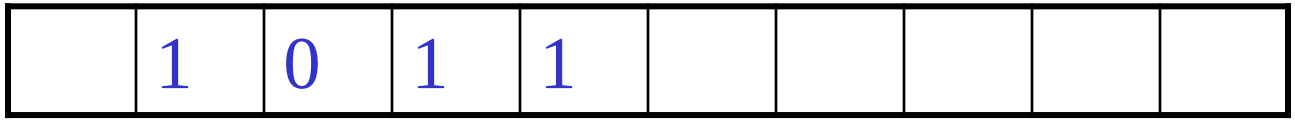
Input image



Structuring Element

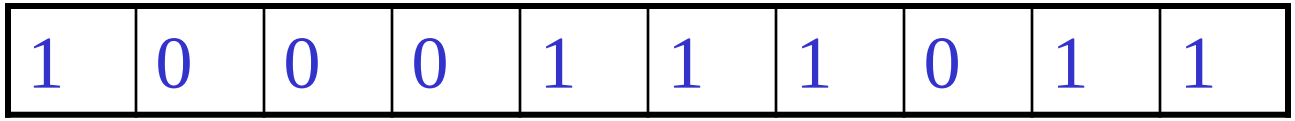


Output Image

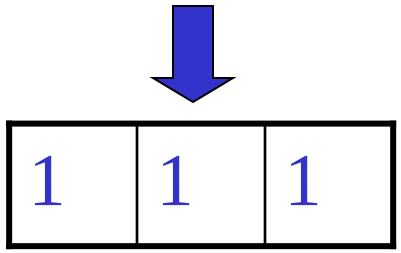


Example for Dilation

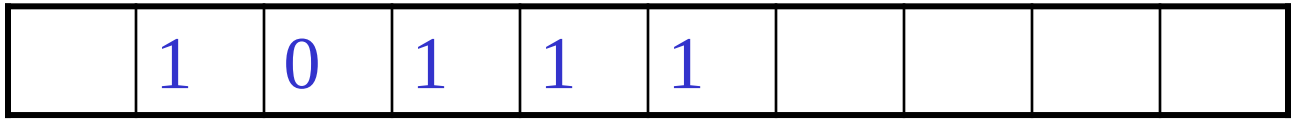
Input image



Structuring Element

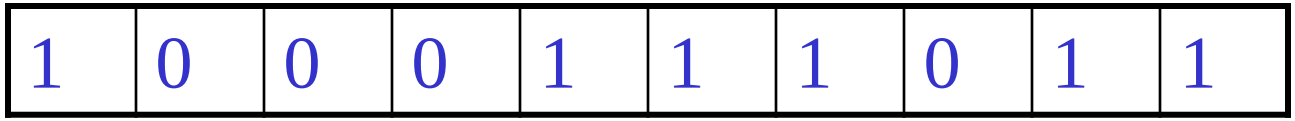


Output Image

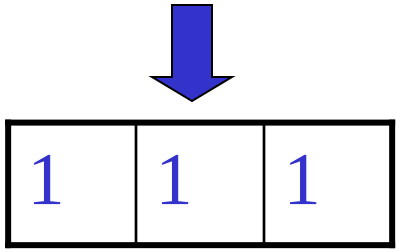


Example for Dilation

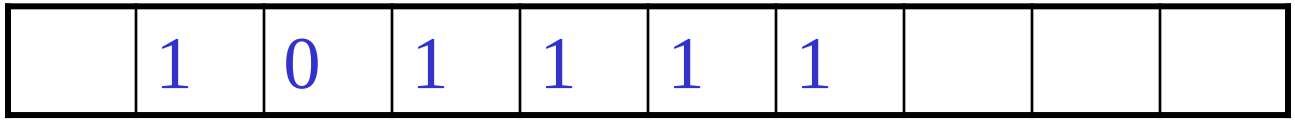
Input image



Structuring Element



Output Image



Example for Dilation

Input image

1	0	0	0	1	1	1	0	1	1

Structuring Element

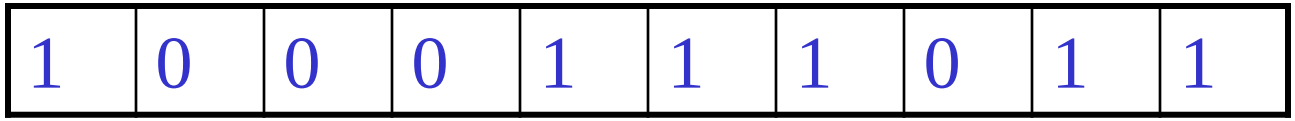
1	1	1

Output Image

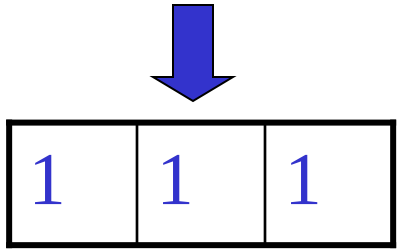
	1	0	1	1	1	1	1		

Example for Dilation

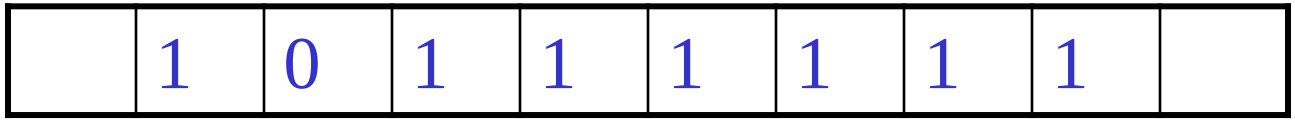
Input image



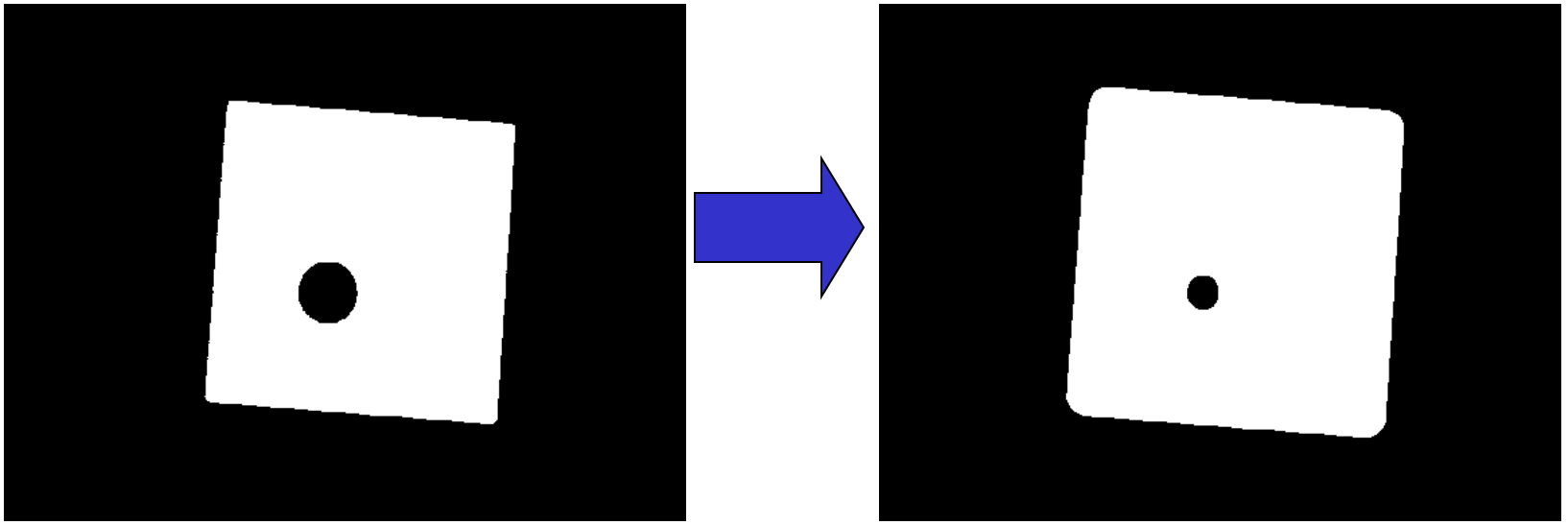
Structuring Element



Output Image



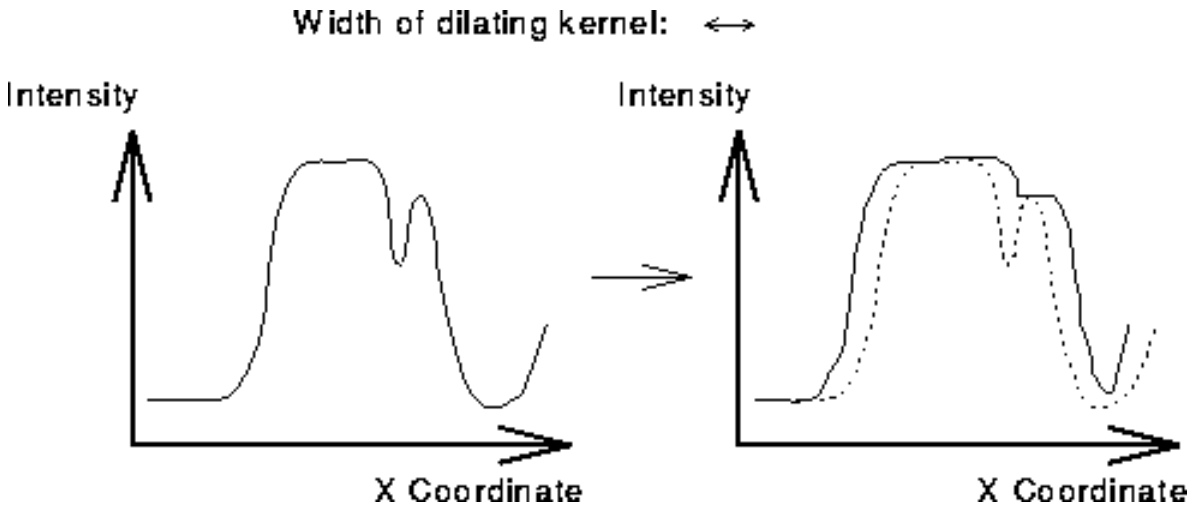
Another Dilation Example



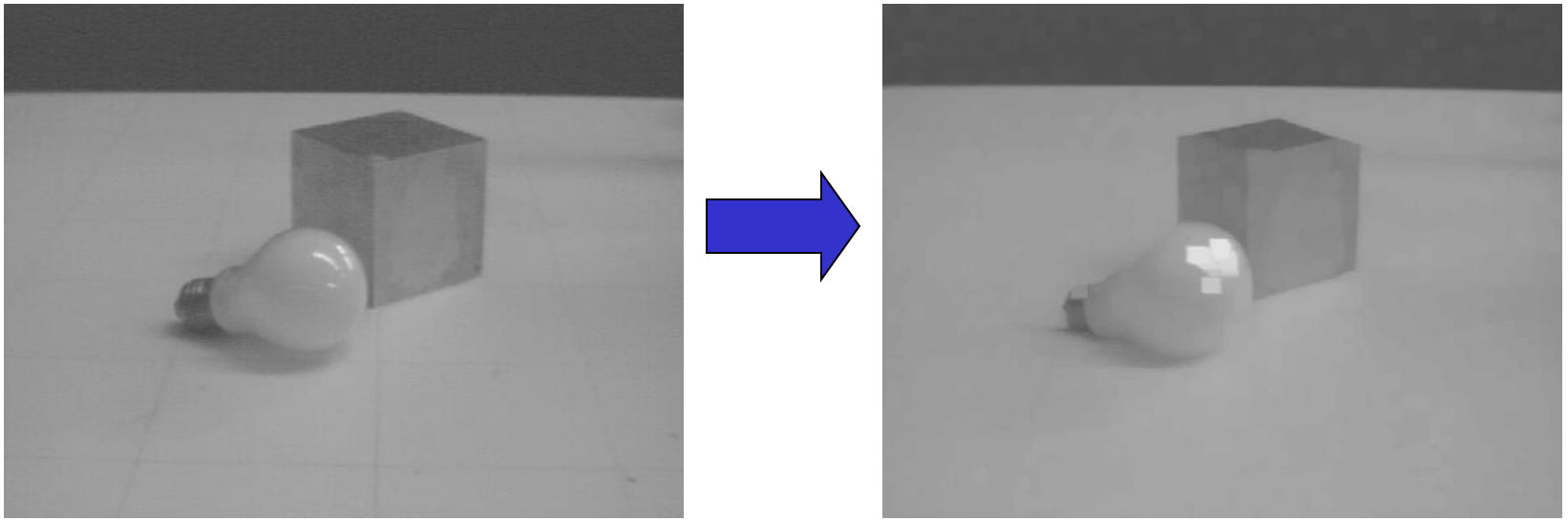
- Image get lighter, more uniform intensity

Dilation on Gray Value Images

- View gray value images as a stack of binary images!



Dilation on Gray Value Images

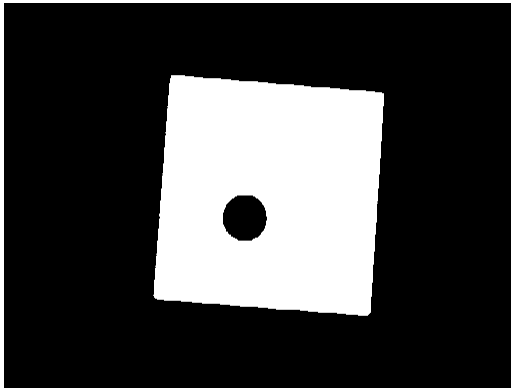
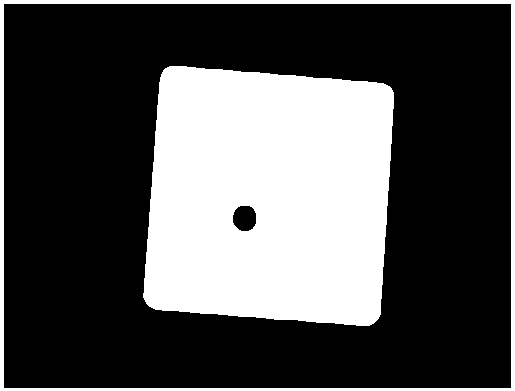
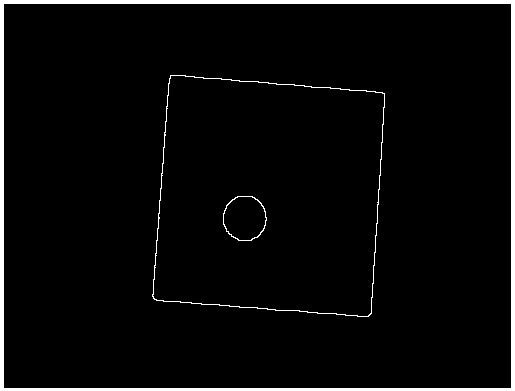


- More uniform intensity

Edge Detection

- Edge Detection

1. Dilate input image
2. Subtract input image from dilated image
3. Edges remain!

Opening & Closing

- Important operations
- Derived from the fundamental operations
  - Dilatation
  - Erosion
- Usually applied to binary images, but gray value images are also possible
- Opening and closing are dual operations

OPENING

Opening

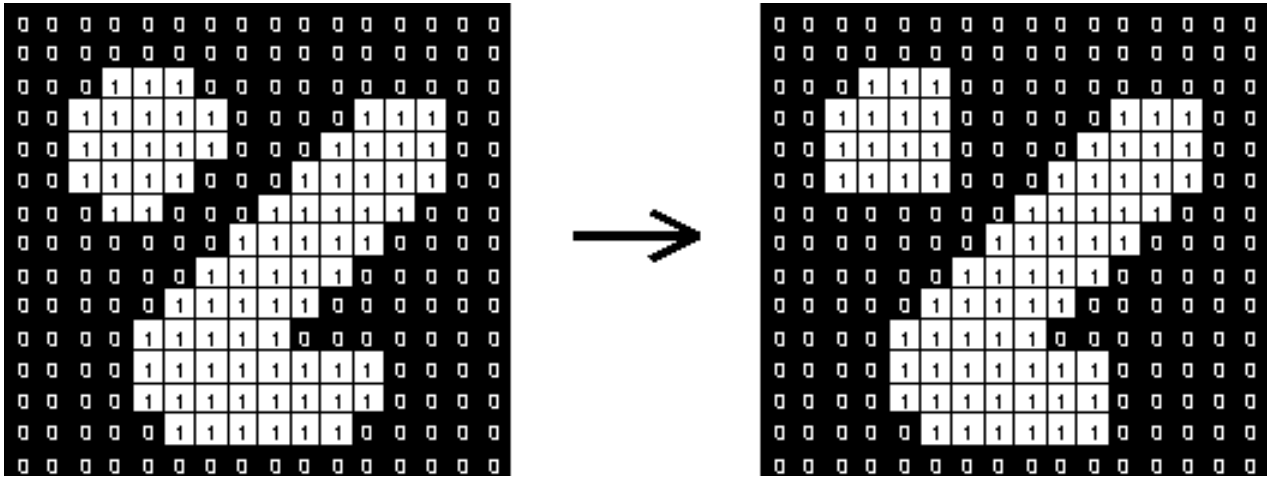
- Similar to Erosion
  - Spot and noise removal
  - Less destructive
- Erosion next dilation
- the s*ame structuring element for both operations*.
- Input:
  - Binary Image
  - Structuring Element, containing only 1s!

Opening

- Take the structuring element (SE) and slide it around *inside* each foreground region.
  - All 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!
- Opening is **idempotent:** Repeated application has no further effects!

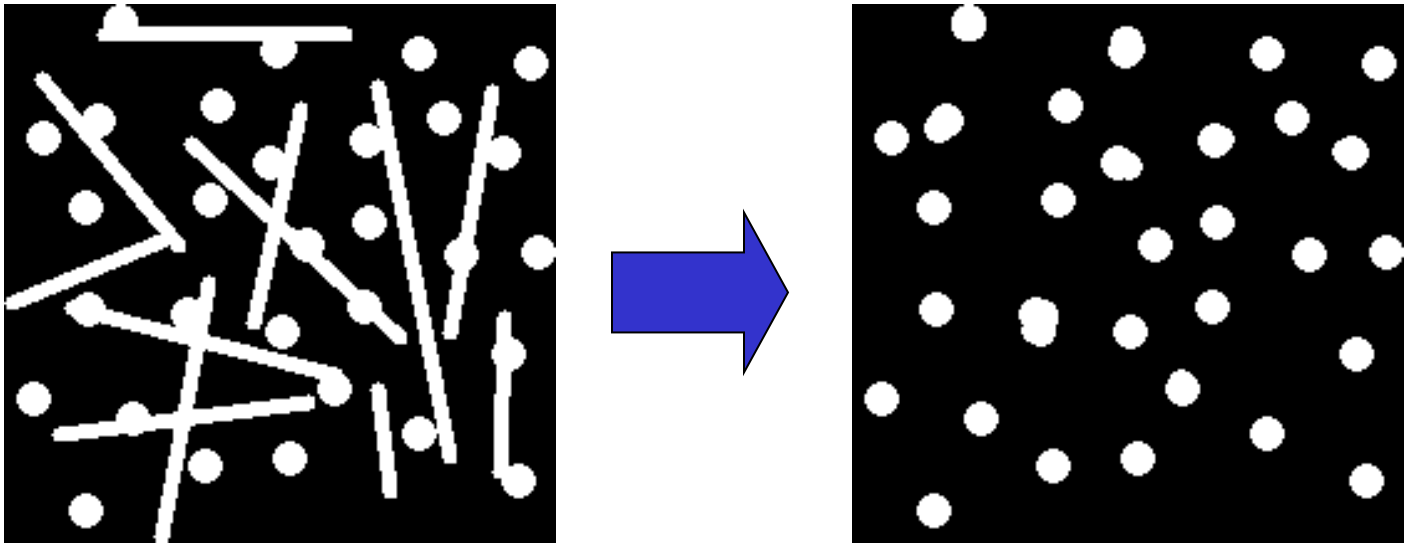
Opening

- Structuring element: 3x3 square



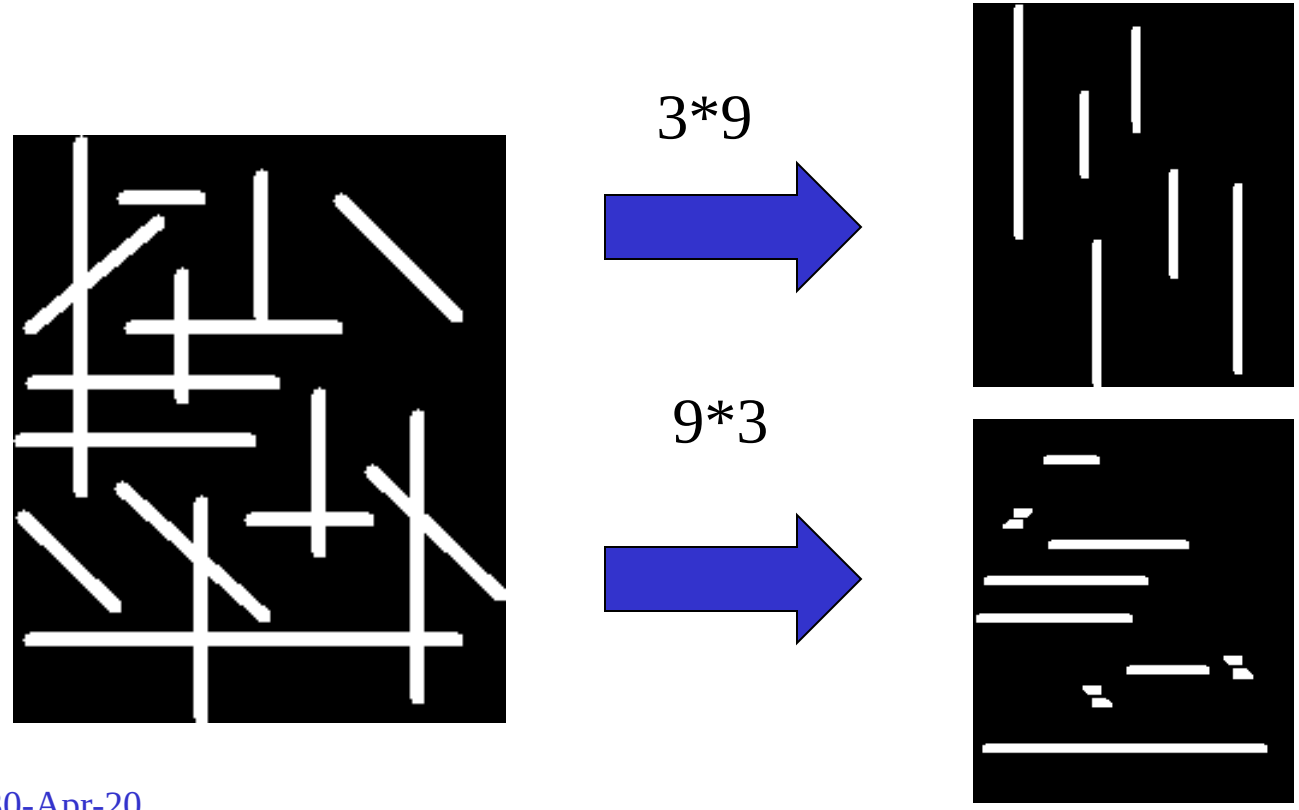
Opening Example

- Opening with a 11 pixel diameter disc



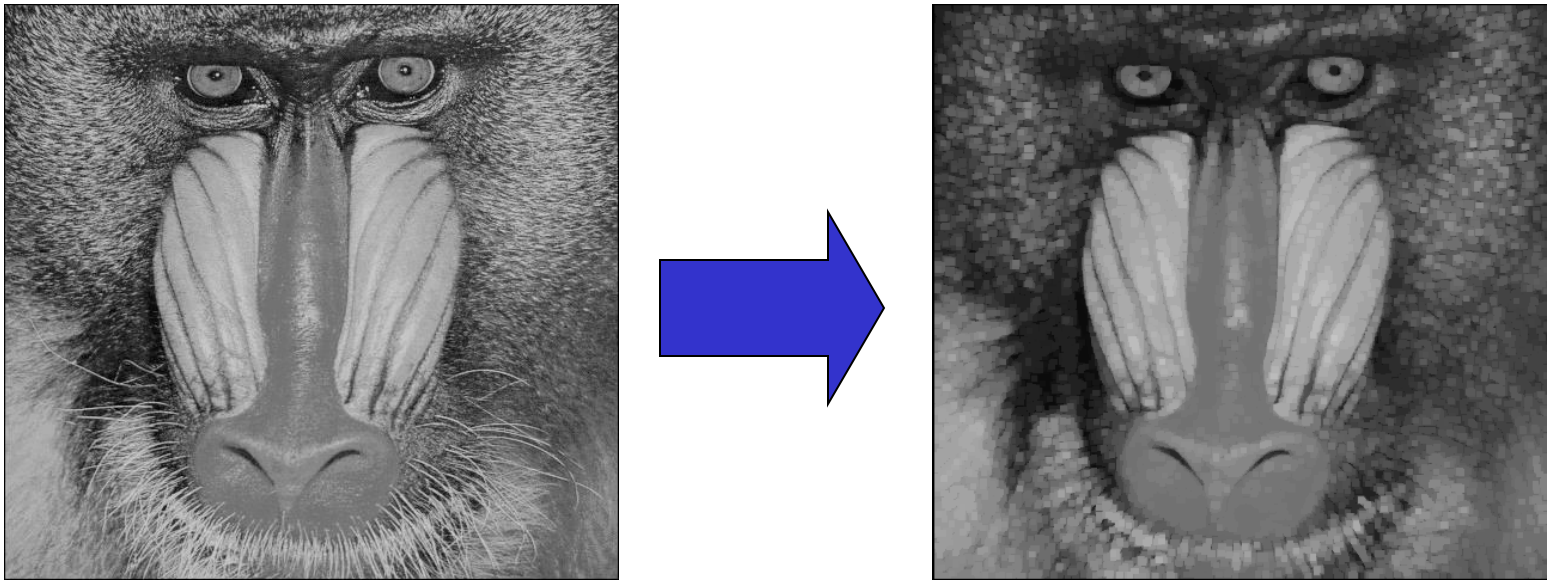
Opening Example

- 3x9 and 9x3 Structuring Element



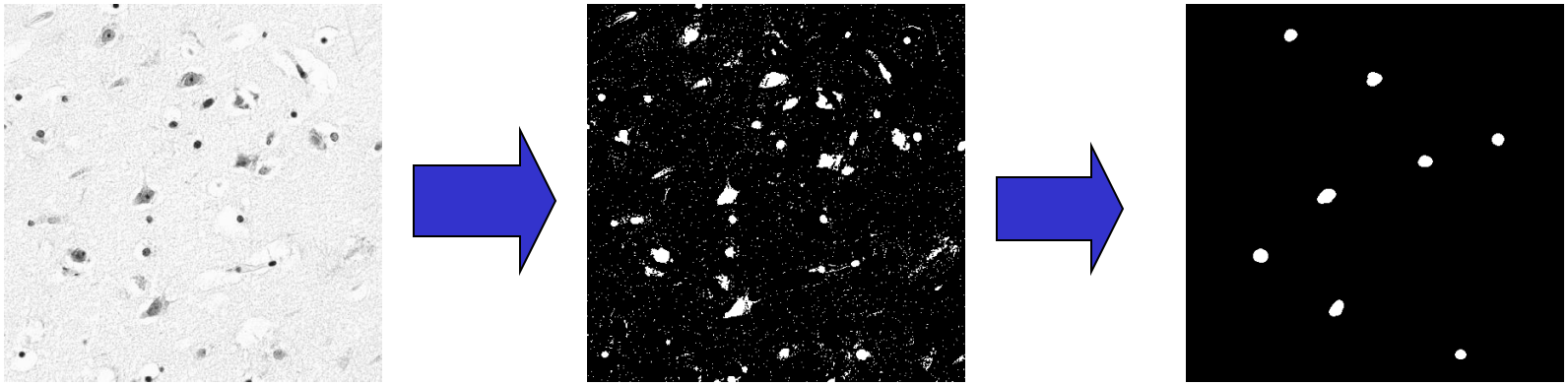
Opening on Gray Value Images

- 5x5 square structuring element



Use Opening for Separating Blobs

- Use large structuring element that fits into the big blobs
- Structuring Element: 11 pixel disc



CLOSING

Closing

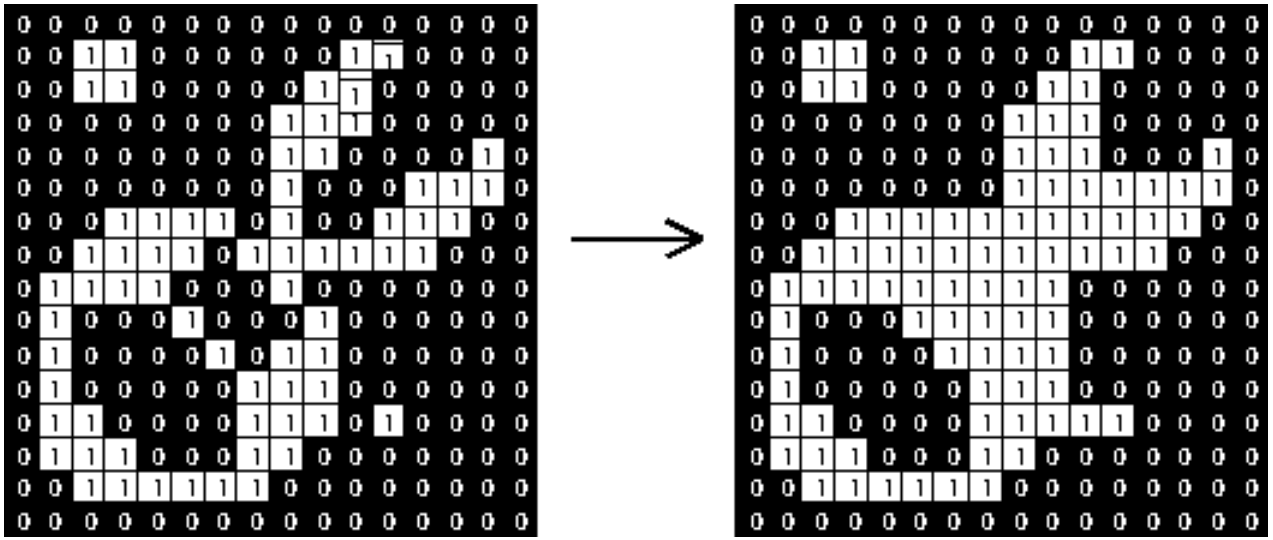
- Similar to Dilation
  - Removal of holes
  - Tends to enlarge regions, shrink background
- Closing is defined as a Dilatation, followed by an Erosion *using the same structuring element for both operations.*
- Dilation next erosion!
- Input:
  - Binary Image
  - Structuring Element, containing only 1s!

Closing

- 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.
- Opening is **idempotent:** Repeated application has no further effects!

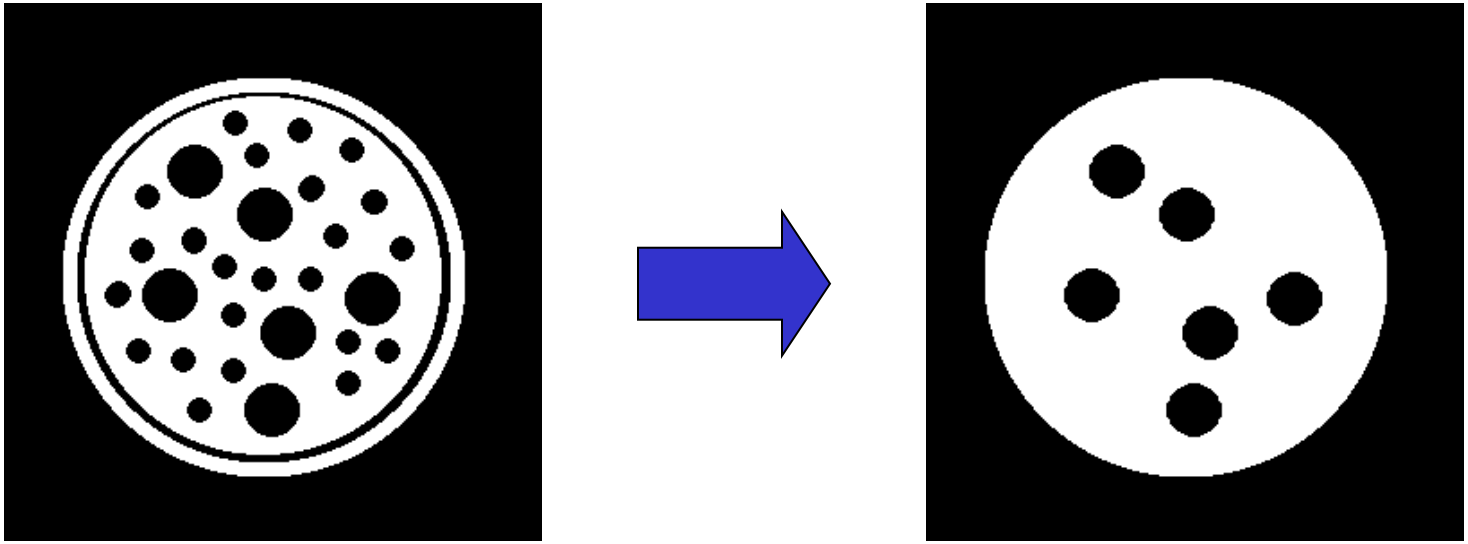
Closing

- Structuring element: 3x3 square



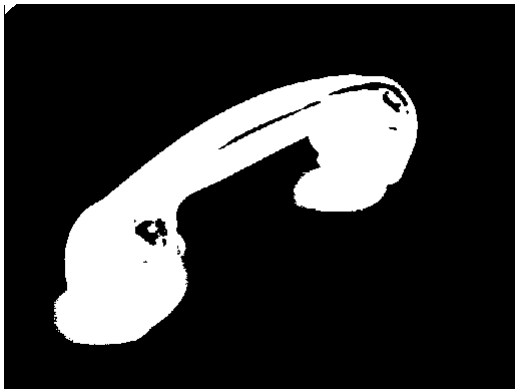
Closing Example

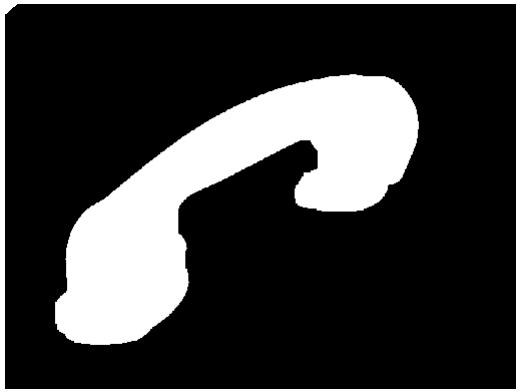
- Closing operation with a 22 pixel disc
- Closes small holes in the foreground



Closing Example 1

1. Threshold
2. Closing with disc of size 20

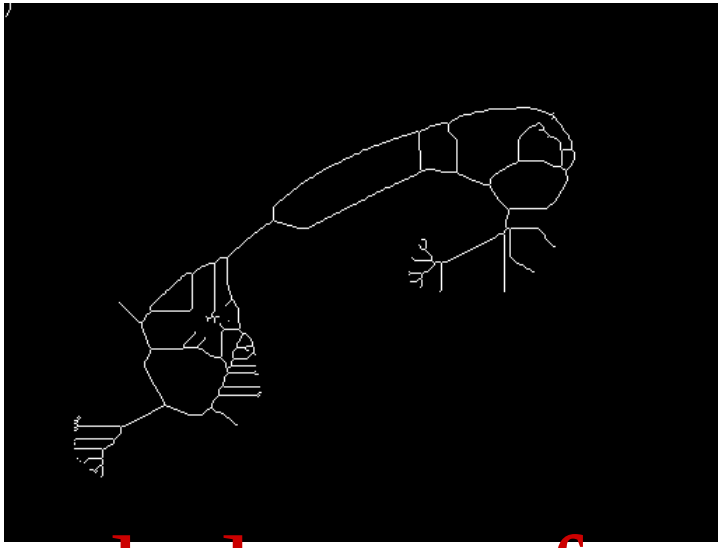




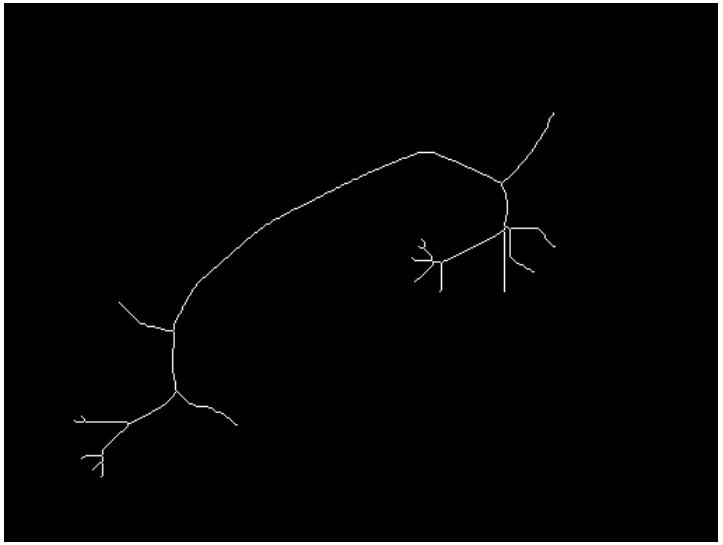
Thresholded closed

Closing Example 2

- Good for further processing: E.g. Skeleton operation looks better for closed image!



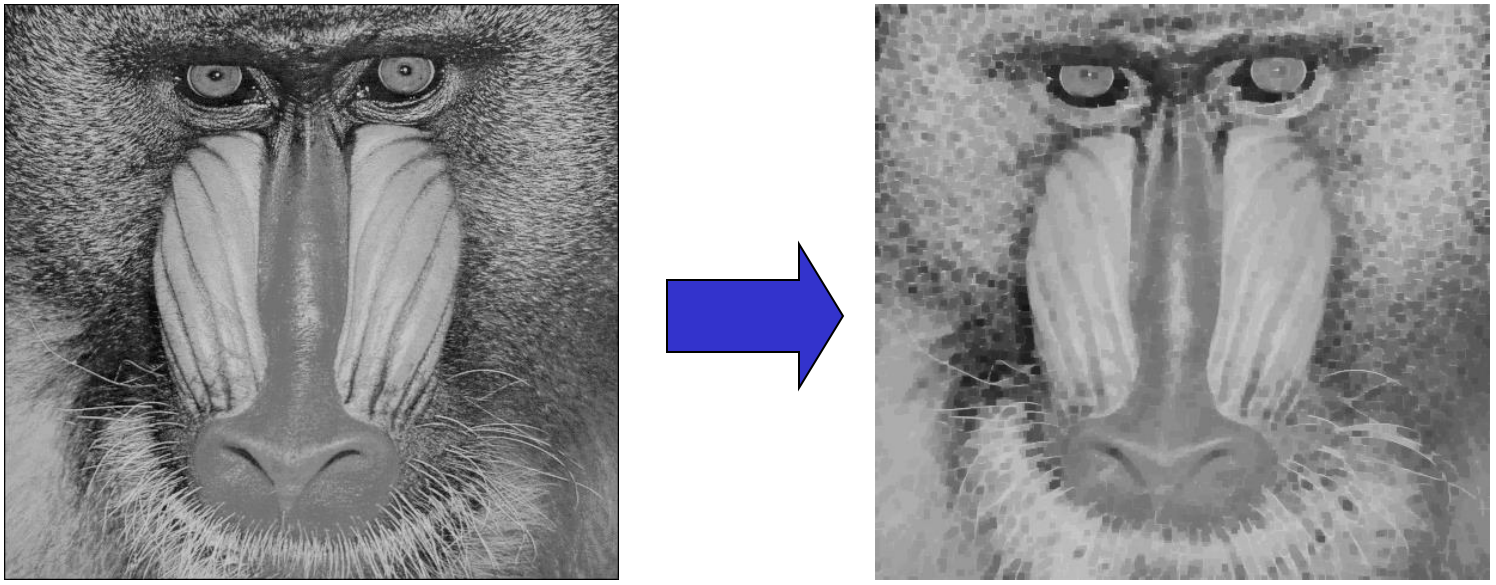
skeleton of Thresholded



skeleton of Thresholded and next closed

Closing Gray Value Images

- 5x5 square structuring element

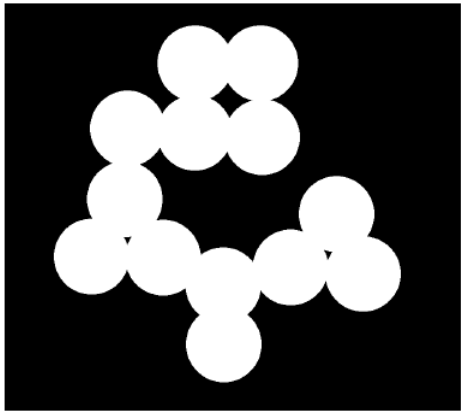


Opening & Closing

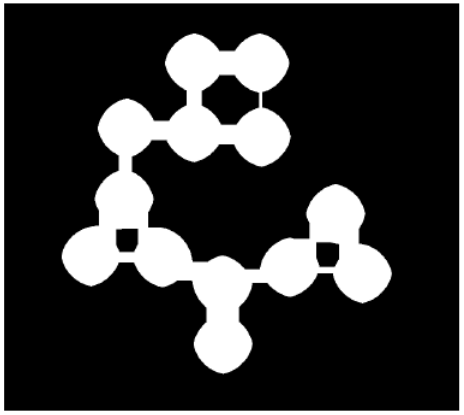
- Opening is the *dual* of closing
- *i.e.* opening the foreground pixels with a particular structuring element
- is equivalent to closing the background pixels with the same element.

Examples

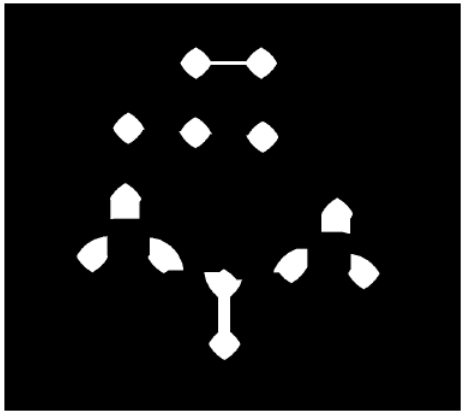
Example: blob separation/detection by erosion



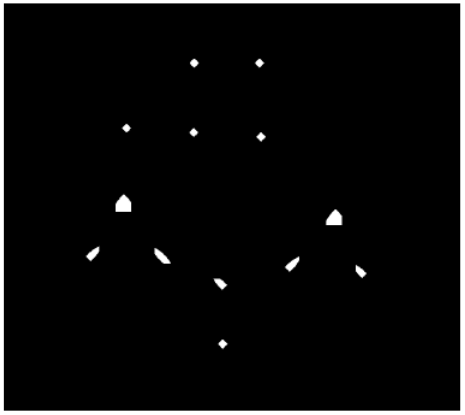
Original binary image
Circles (792x892)



Erosion by 30x30
structuring element

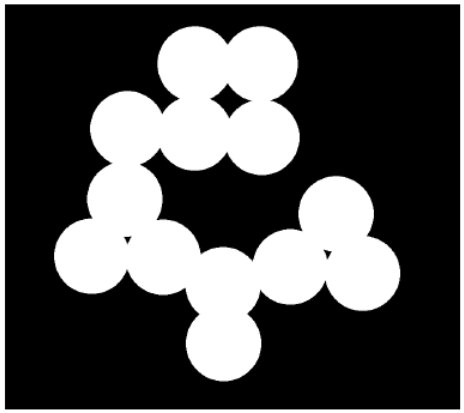


Erosion by 70x70
structuring element

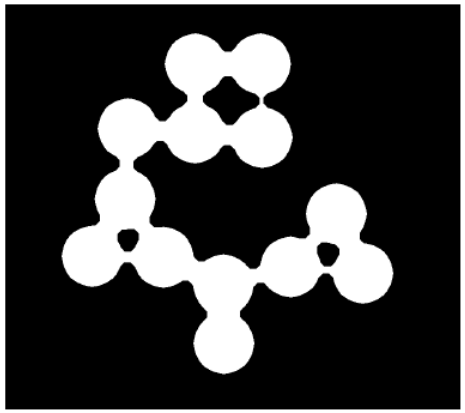


Erosion by 96x96
structuring element

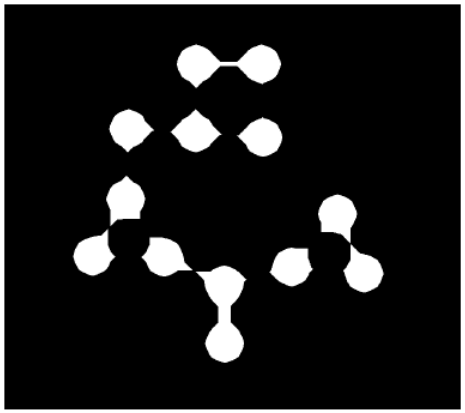
Example: blob separation/detection by erosion



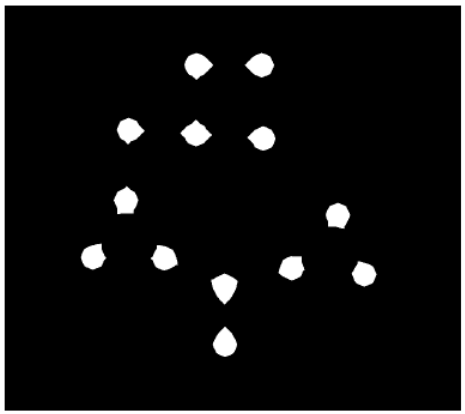
Original binary image
Circles (792x892)



Erosion by disk-shaped structuring element
Diameter=15

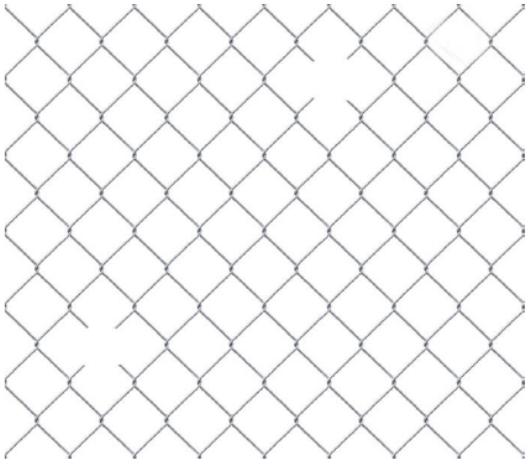


Erosion by disk-shaped structuring element
Diameter=35

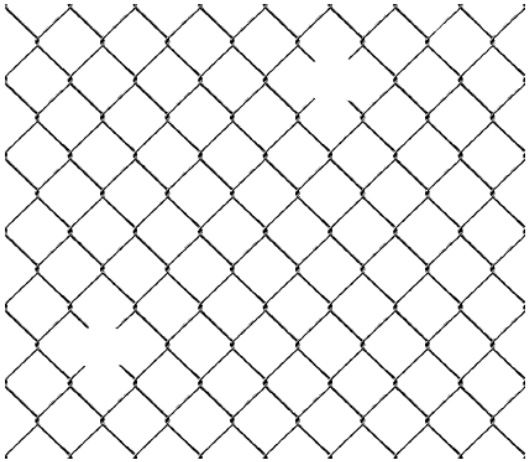


Erosion by disk-shaped structuring element
Diameter=48

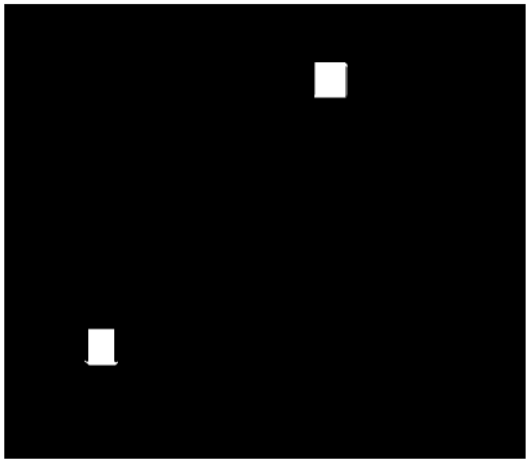
Example: chain link fence hole detection



Original grayscale image
Fence (1023 x 1173*)*



Fence thresholded
using Otsu's method

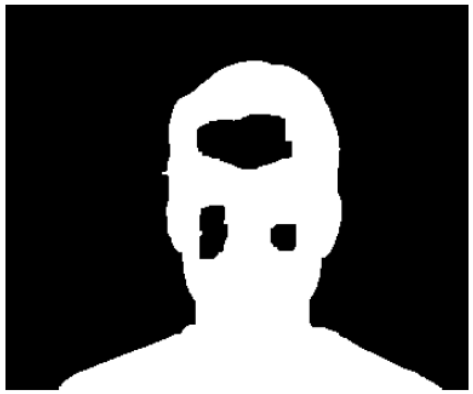


Erosion with 151x151
"cross" structuring element

Small hole removal by closing

Original binary mask

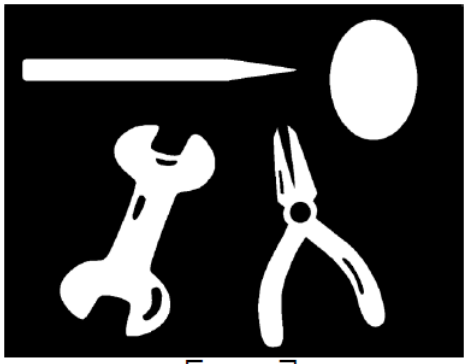
Dilation
10x10



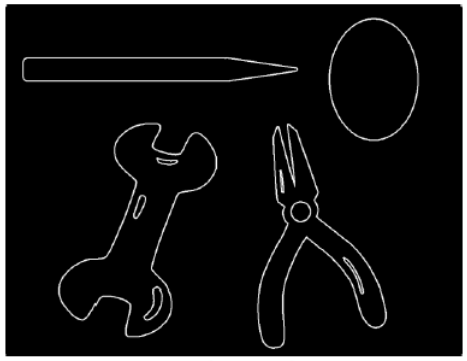
Closing 10x10

Difference to original mask

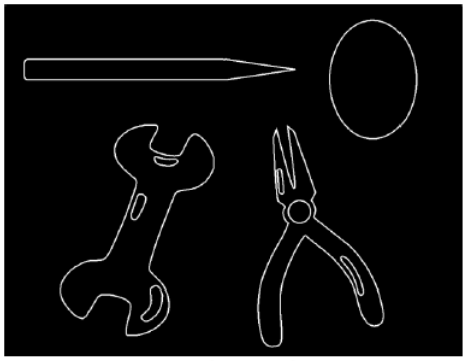
Morphological edge detectors



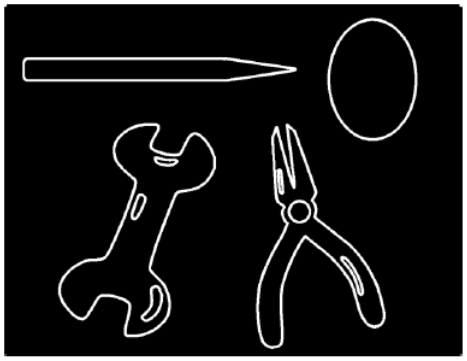
$f[x,y]$



$dilate(f,W) \neq f$



$erode(f,W) \neq f$



$dilate(f,W) \neq erode(f,W)$

Morphological edge detector

original f

dilation g

$g - f$

$g - f$ thresholded