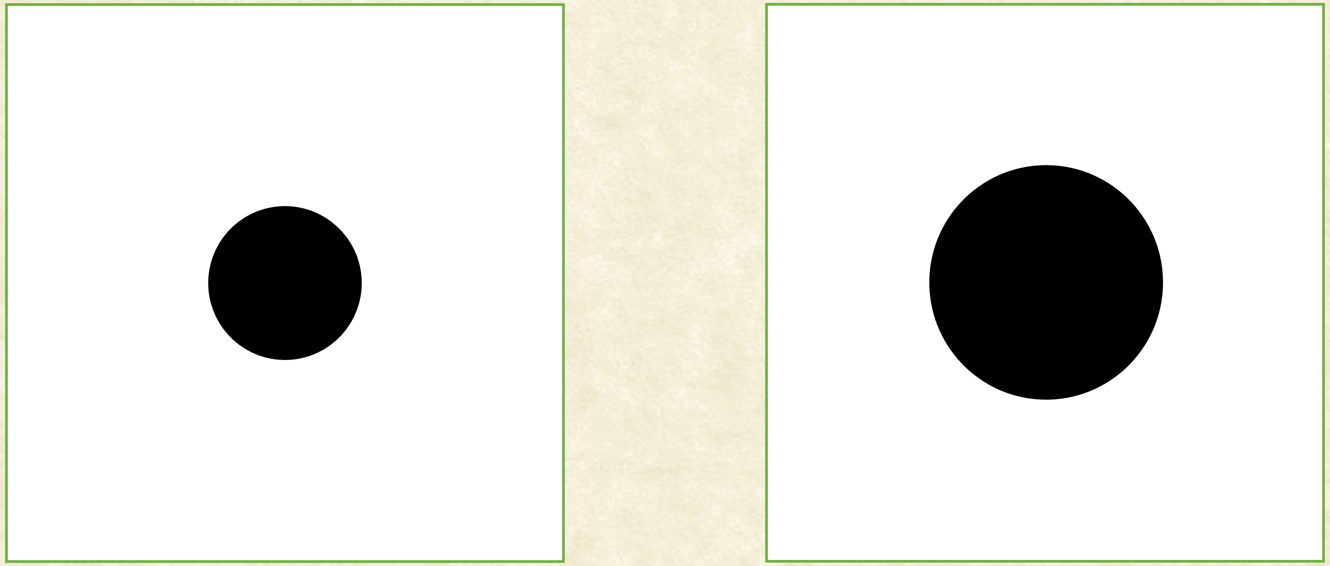
CS7.404: Digital Image Processing

Monsoon 2023: Morphological Image Processing 1



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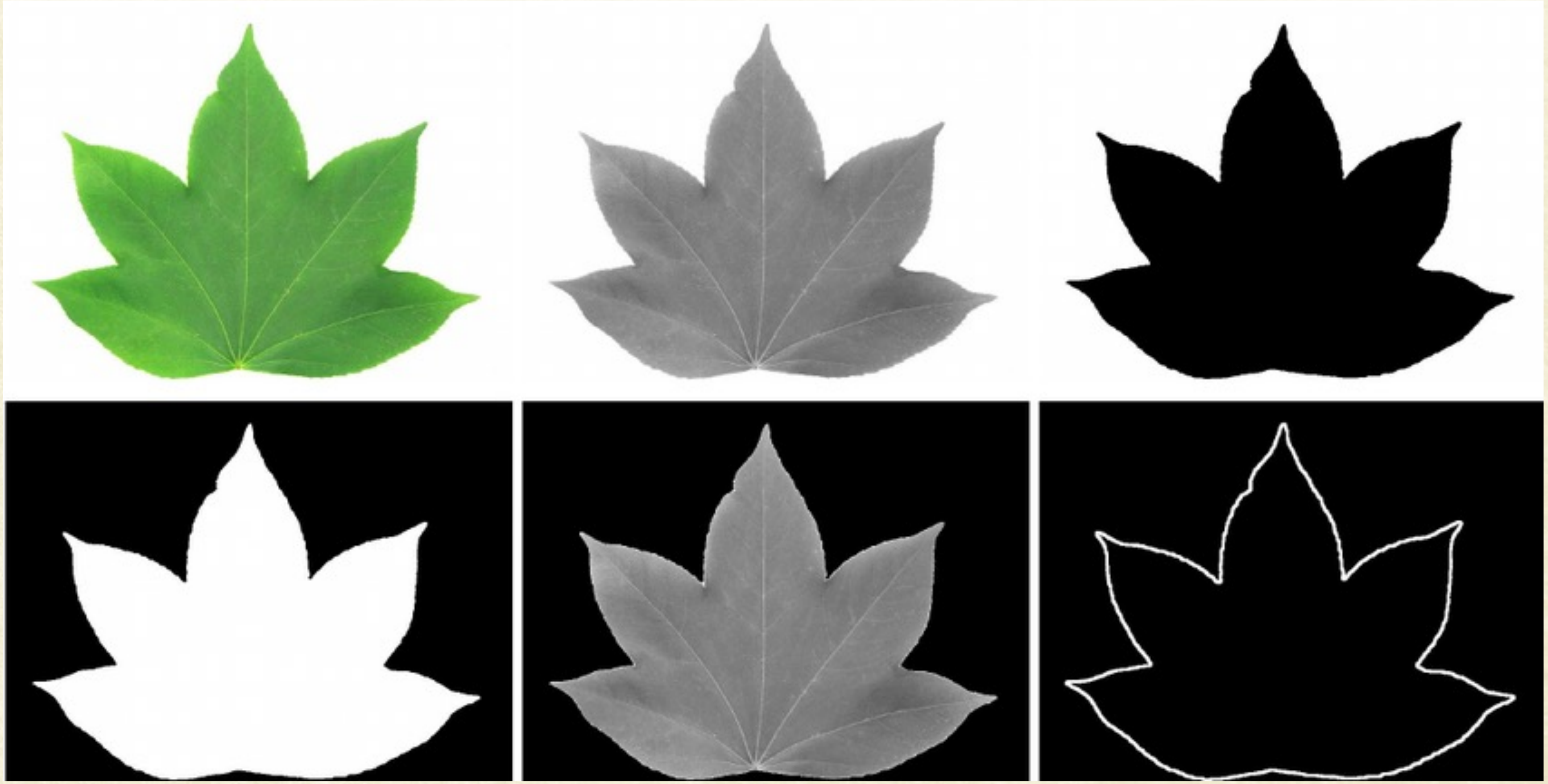
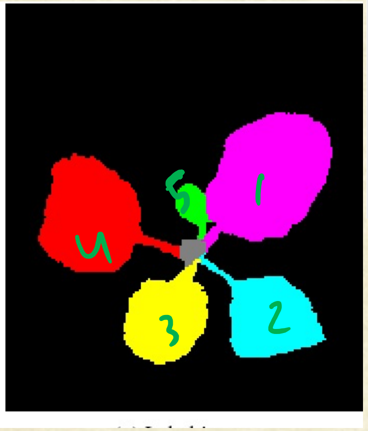
IIIT Hyderabad

Plant Phenotyping





Recognizing Scene Text

https://cvit.iiit.ac.in/research/projects/cvit-projects/scene-text-understanding

Document Image Analysis

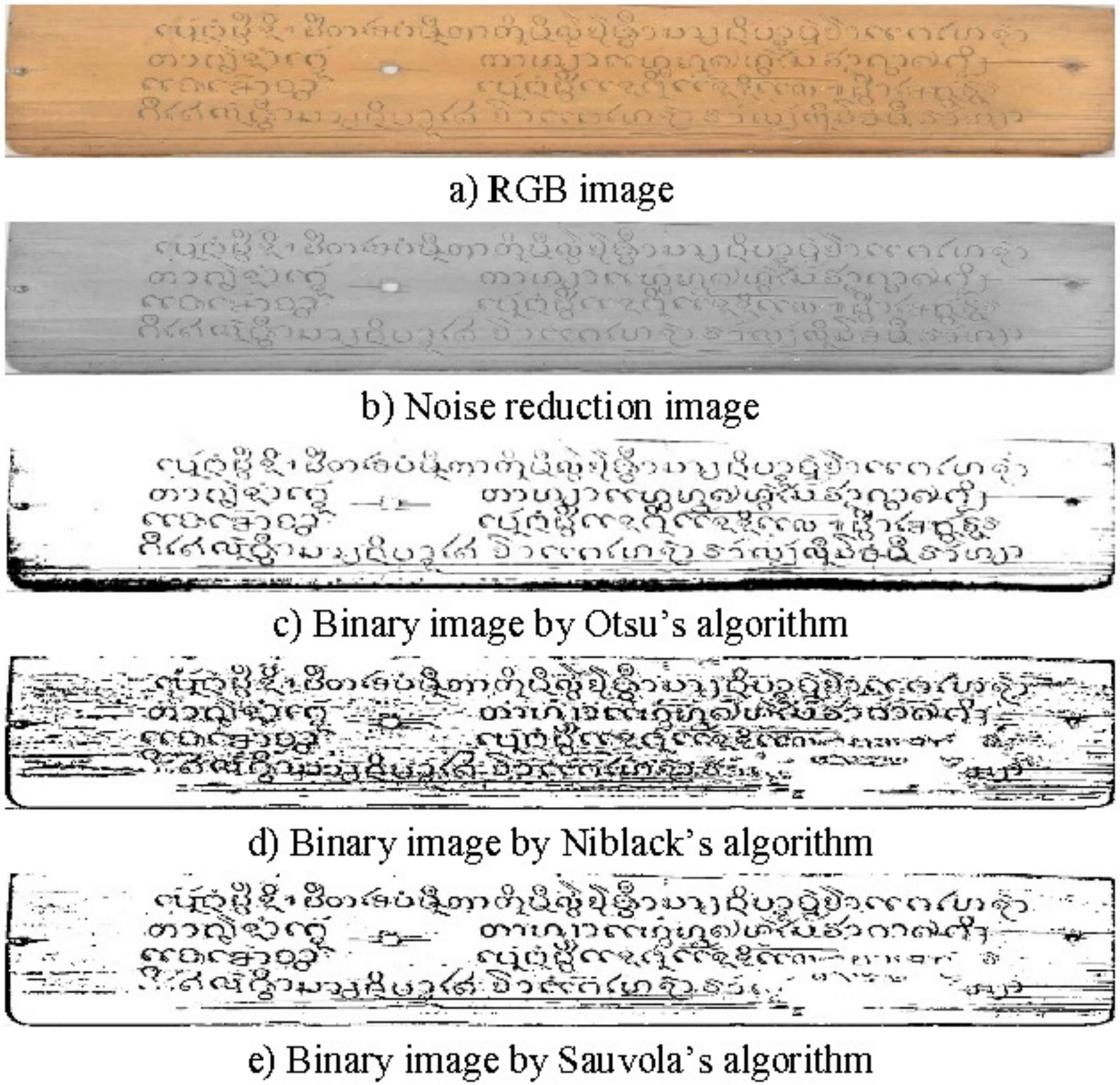


Figure 2. Samples of palm leaf images

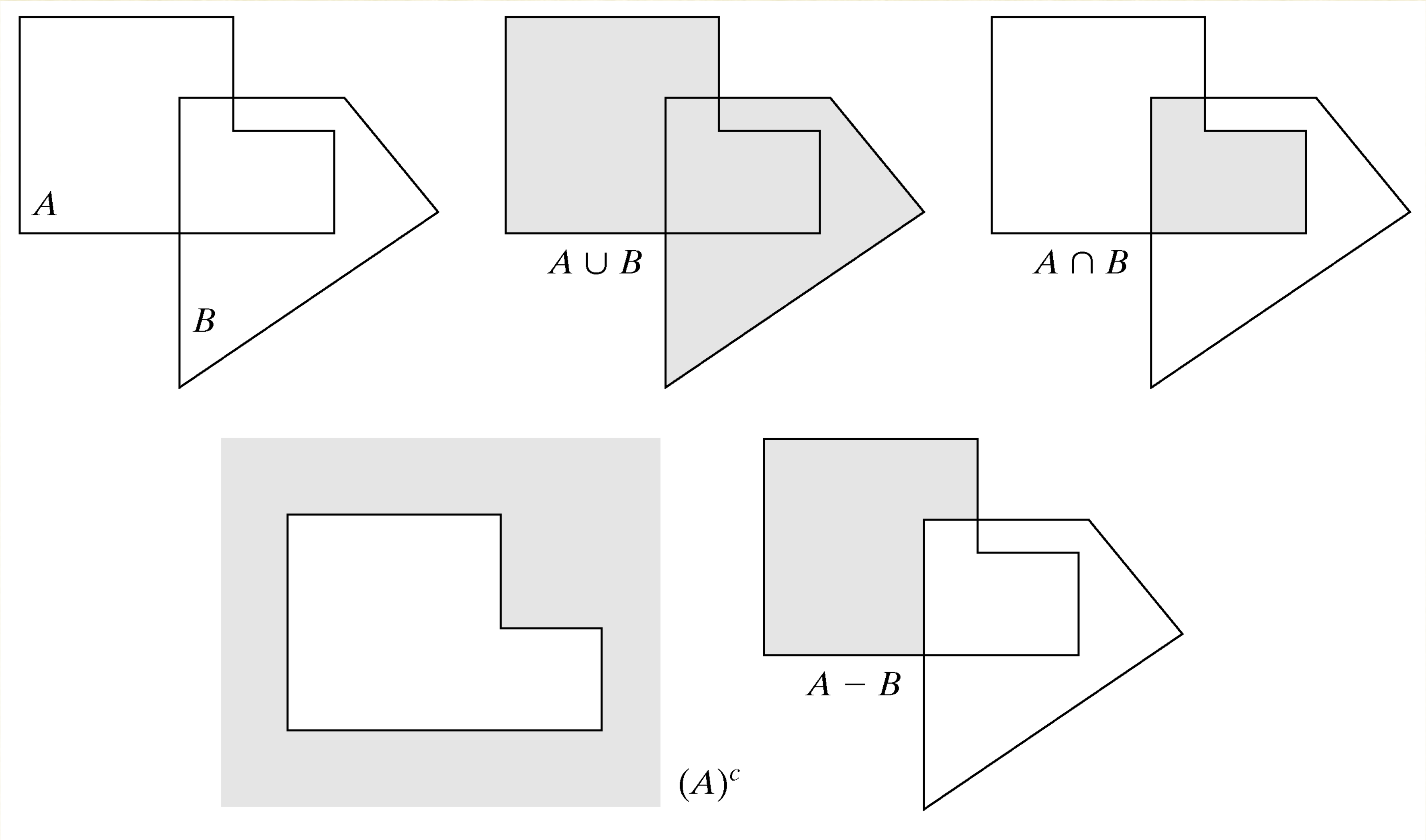
Background Subtraction

Image – Set of Pixels

- Basic idea:
  - Object/Region = <u>set of pixels</u> (or coordinates of pixels)

- 0 = background
- 1 = foreground

Basic Operations

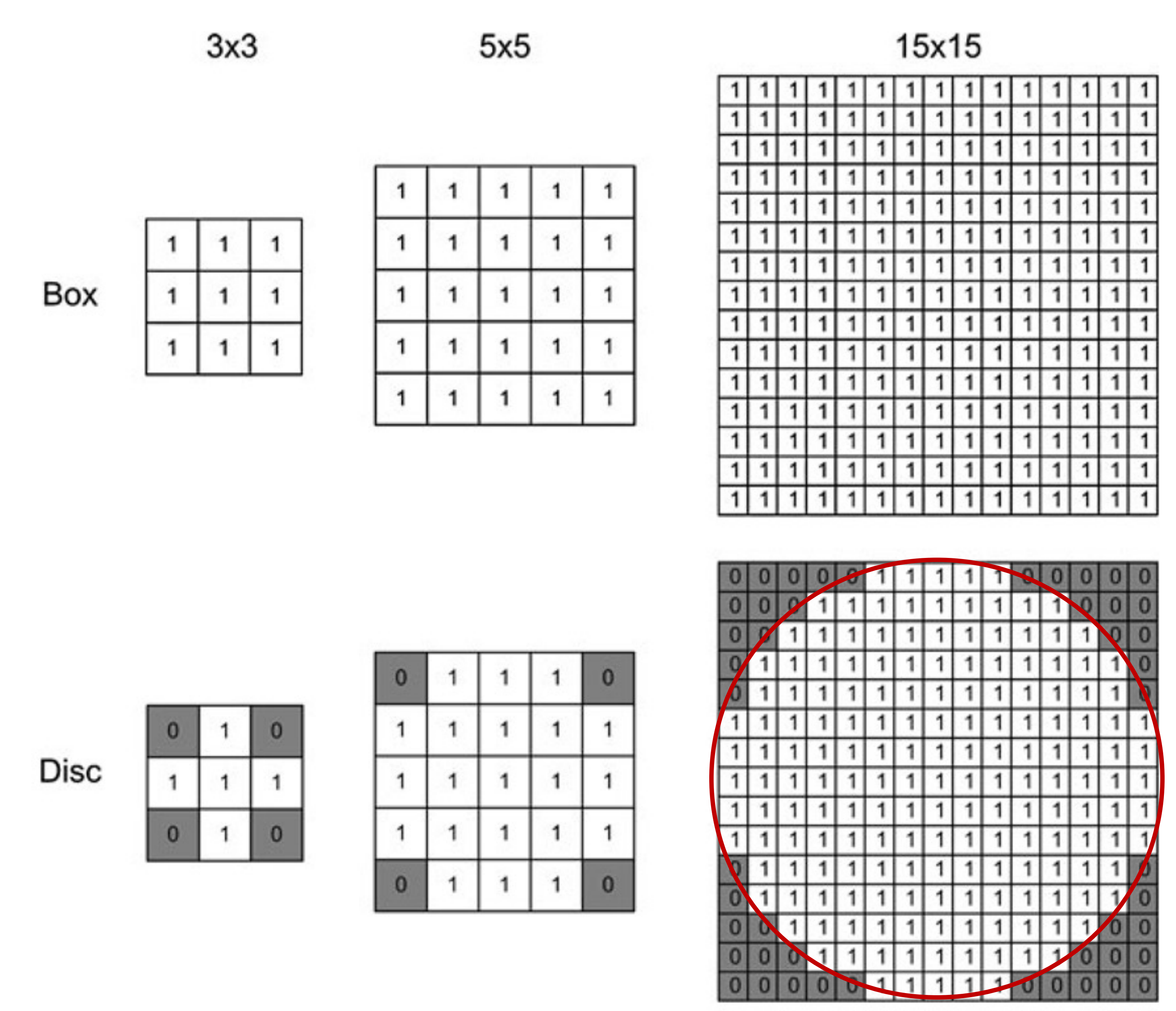


a b c
d e

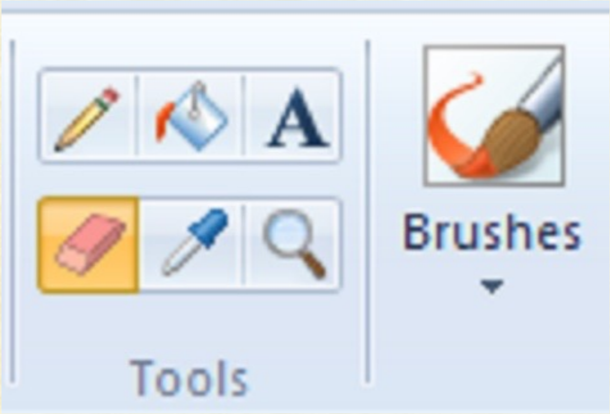
FIGURE 9.1
(a) Two sets A and B. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B.

Basic operations on shapes

Structuring Element



Structuring Element (Kernel)



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

Box

1	1	1
1	1	1
1	1	1

Disc

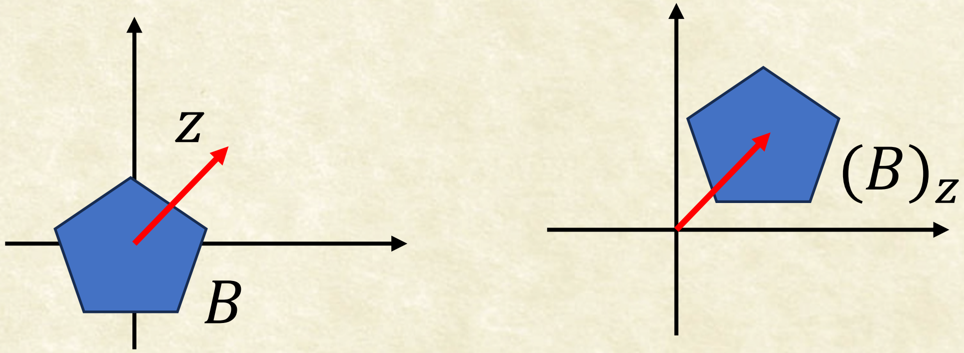
	1	
1	1	1
	1	

		1	1	1		
	1	1	1	1	1	
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
	1	1	1	1	1	
		1	1	1		

1	1	
1	0	
1		0

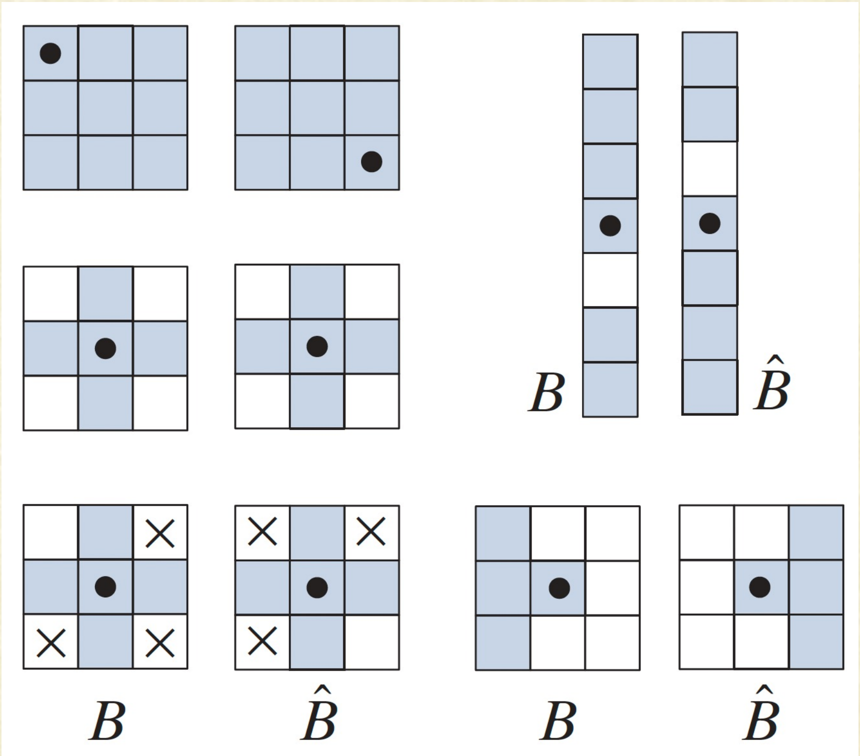
1	1	1
1	10	1
1	1	1

Operations on Structuring Elements



- $(B)_z = \{c \mid c = b + z, \text{for } b \in B\}$

- $\hat{B} = \{w \mid w = -b, b \in B\}$



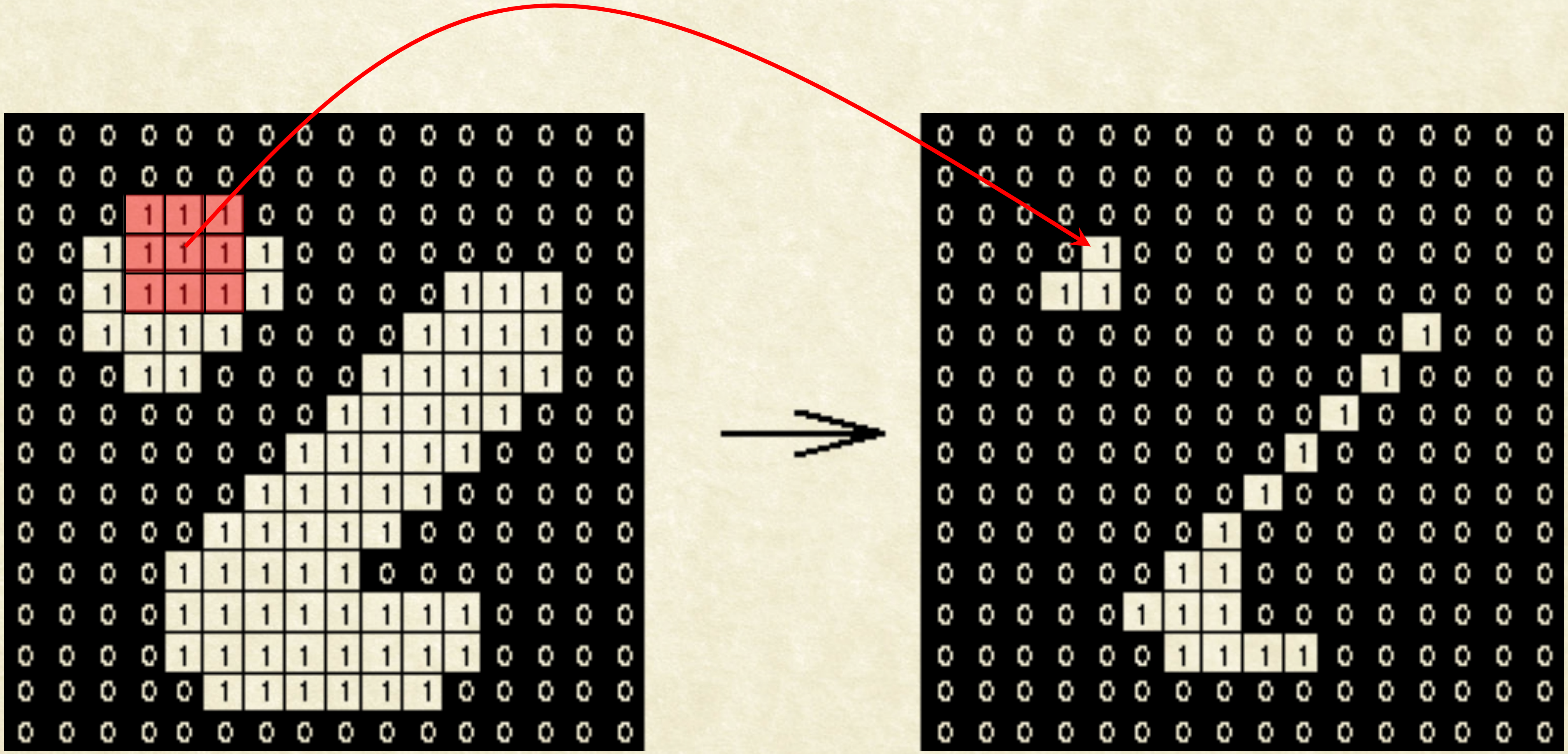
Erosion

Erosion

Erosion: Effect

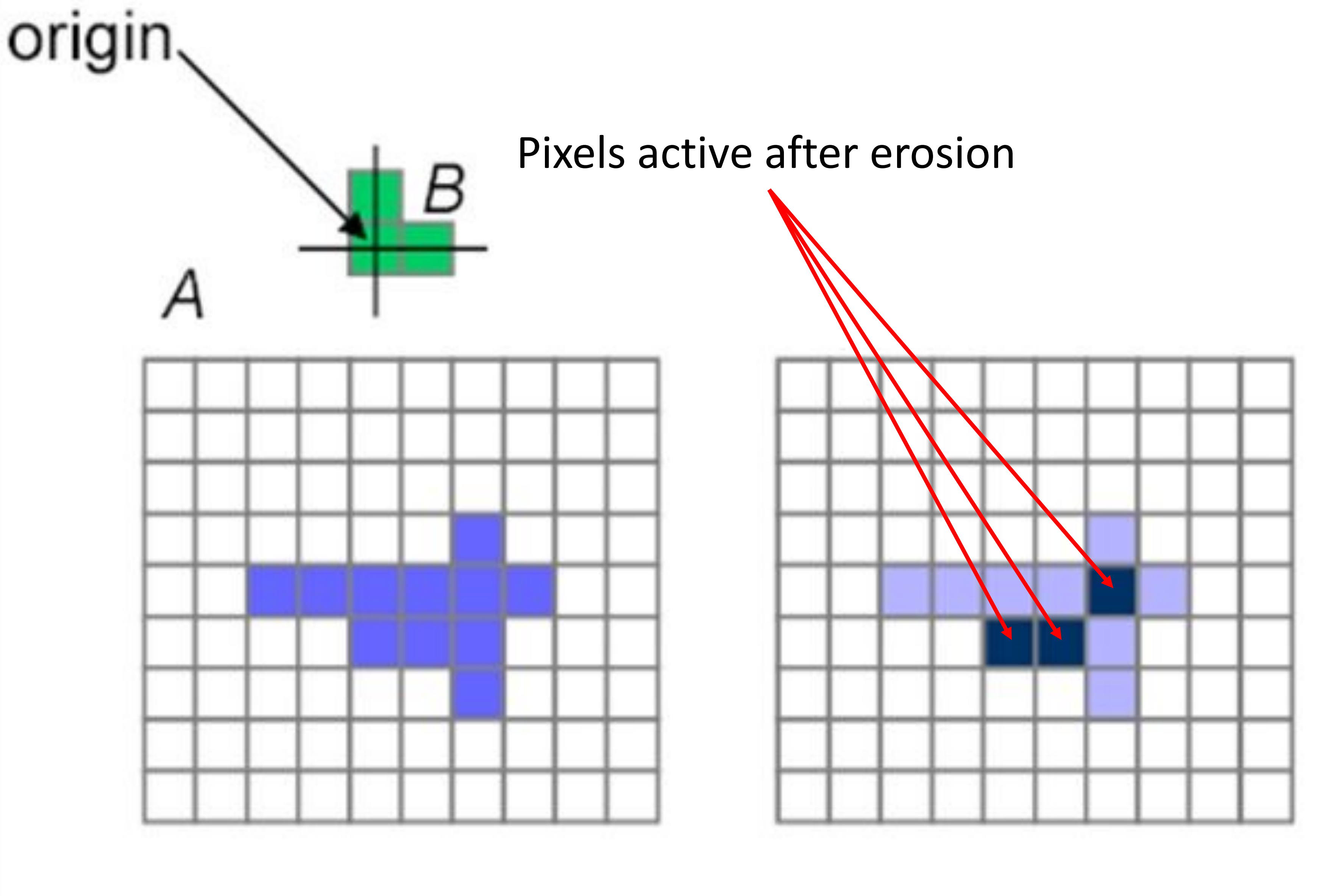
1	1	1
1	1	1
1	1	1

If, for a particular location of Structuring Element (SE) origin, SE lies **fully within the region**, retain the location, else set to 0



SEs Operate w.r.t. an origin

$$A \ominus B = \{z | (B)_z \subseteq A\}$$



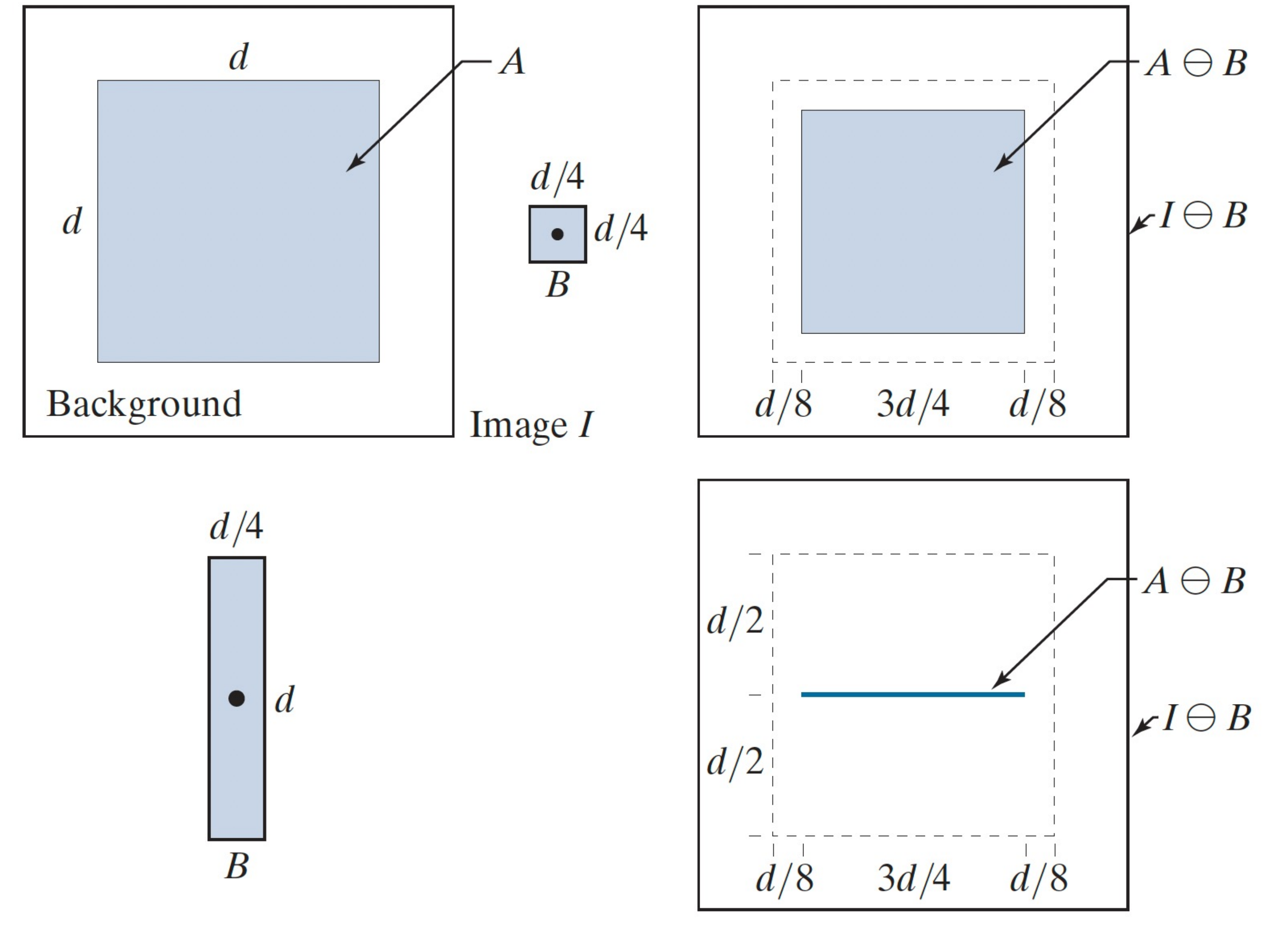
Erosion: Effect of Structuring Element

$$A \ominus B = \{z \mid (B)_z \subseteq A\}$$

The shape of SE decides the directions of removal of foreground pixels

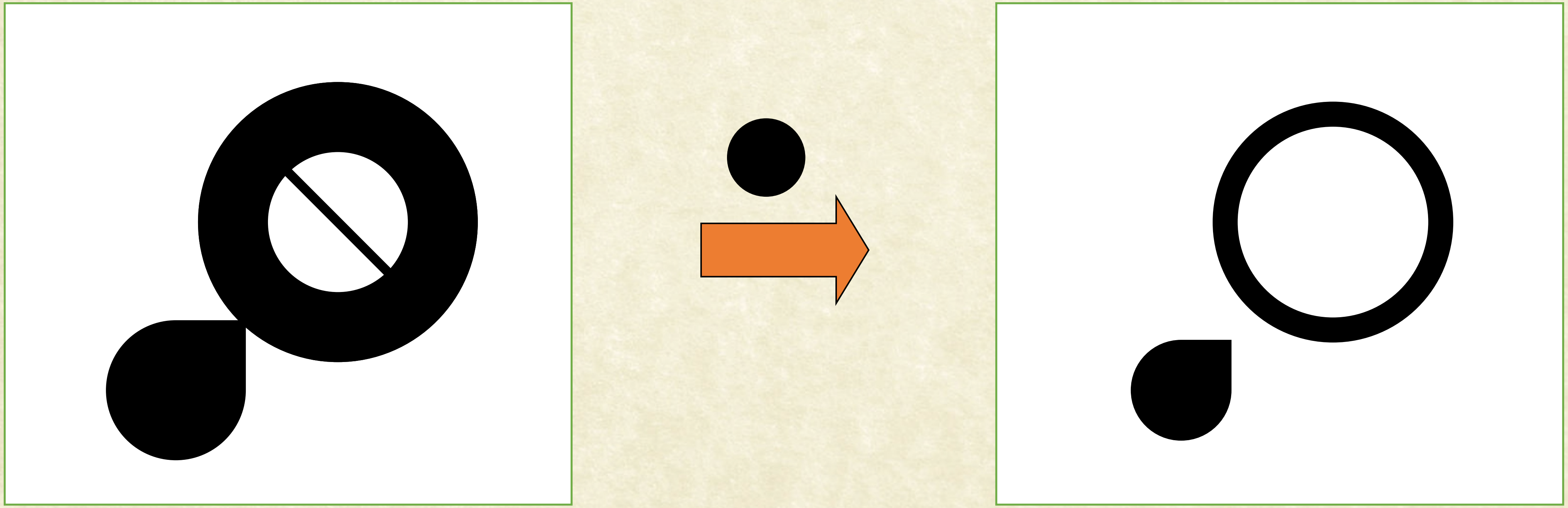
Alternately:

$$A \ominus B = \{z \mid (B)_z \cap A^c = \emptyset\}$$



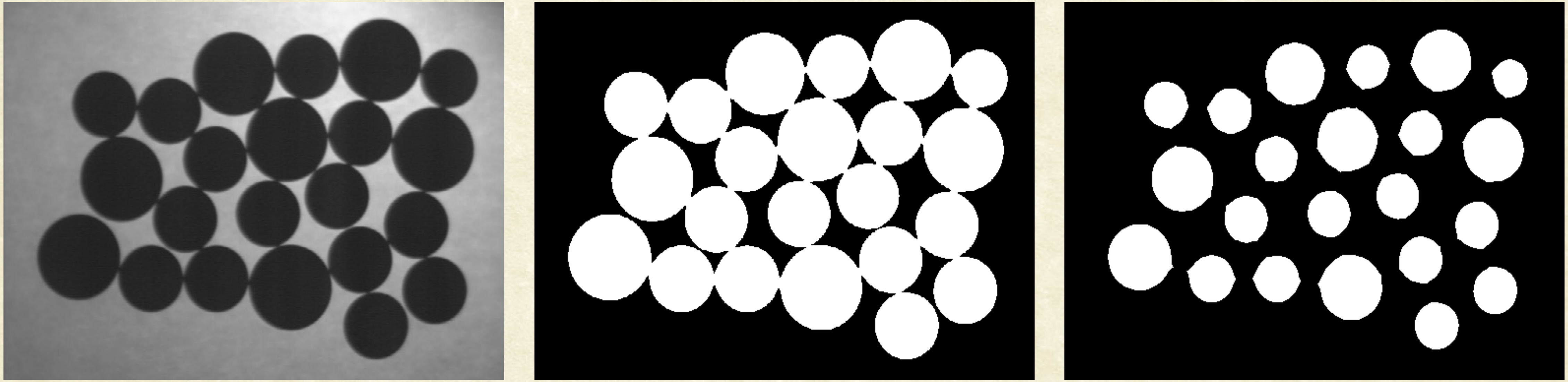
Erosion

- Shrinks foreground objects
- Thin features are removed
- Touching objects are separated
- NOTE: Multiple iterations of dilation

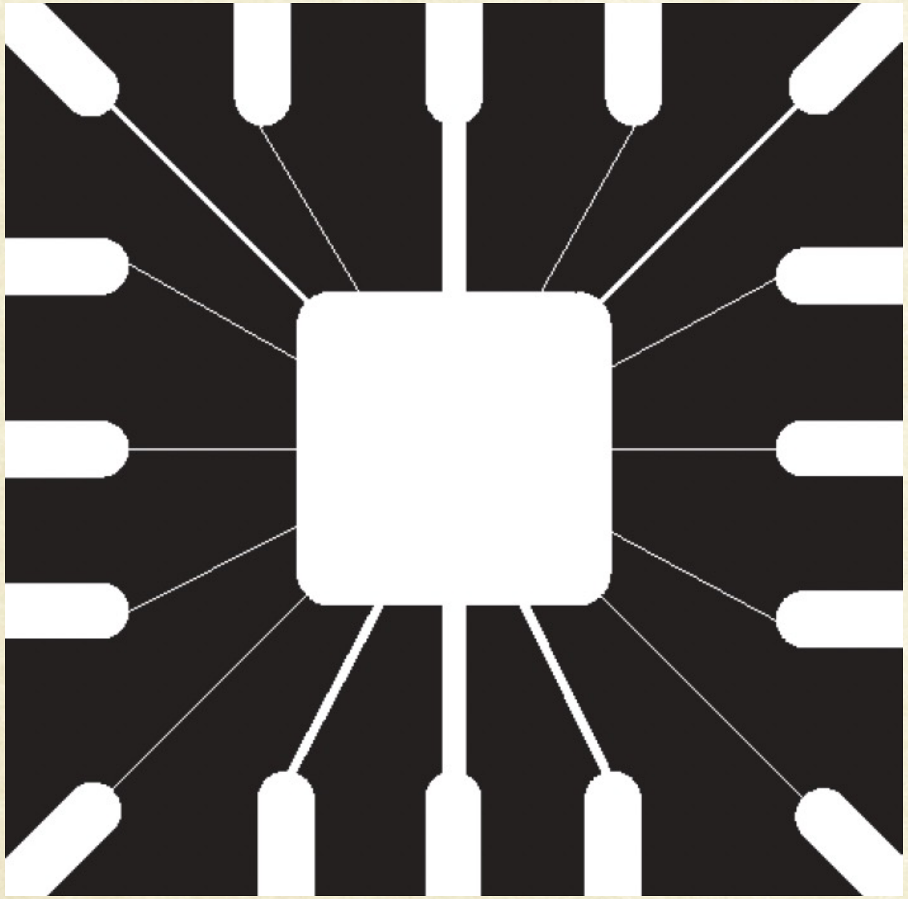


Example: Counting coins

- Difficult because they touch each other!
- Solution: Binarization and Erosion separates them!

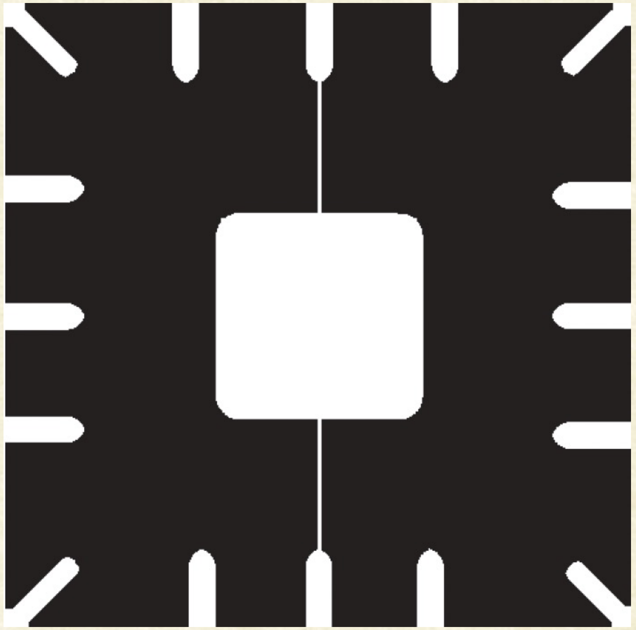


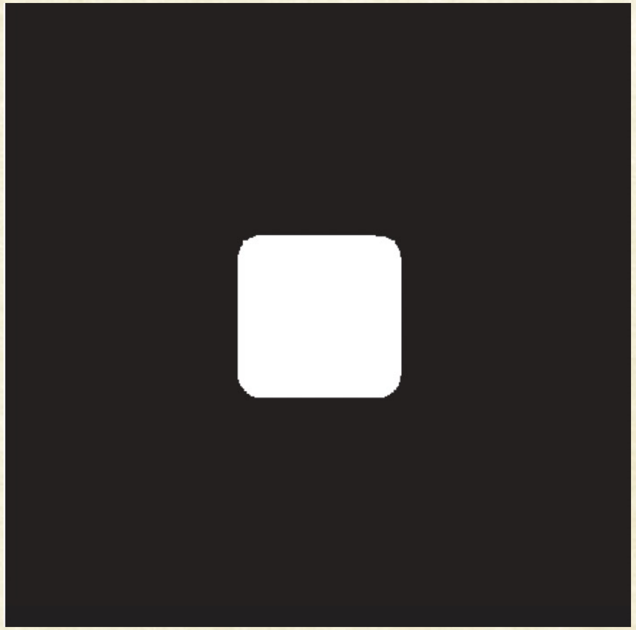
Erosion: Example



486 x 486 image

From: Digital Image Processing, Gonzalez,& Woods

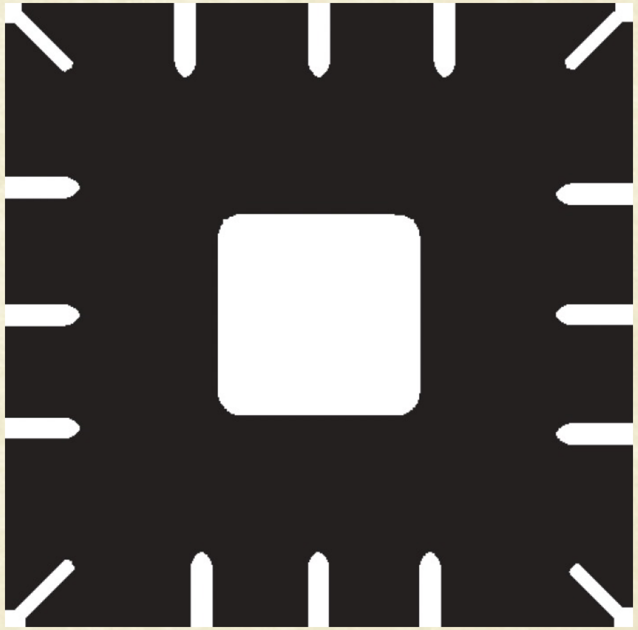




Erosion by square SE:

11 x 11 45 x 45

15 x 15



Erosion operation and min filter

1	1	1
1	1	1
1	1	1

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

$\rightarrow$

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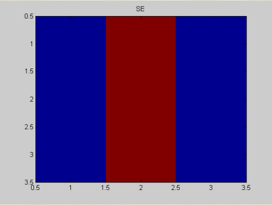
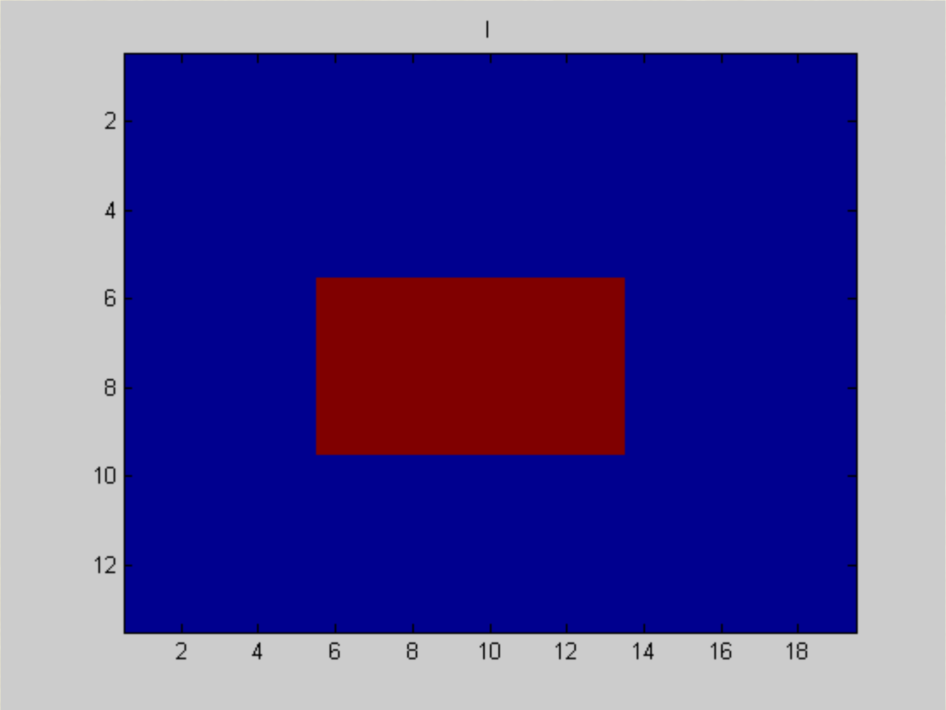
0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

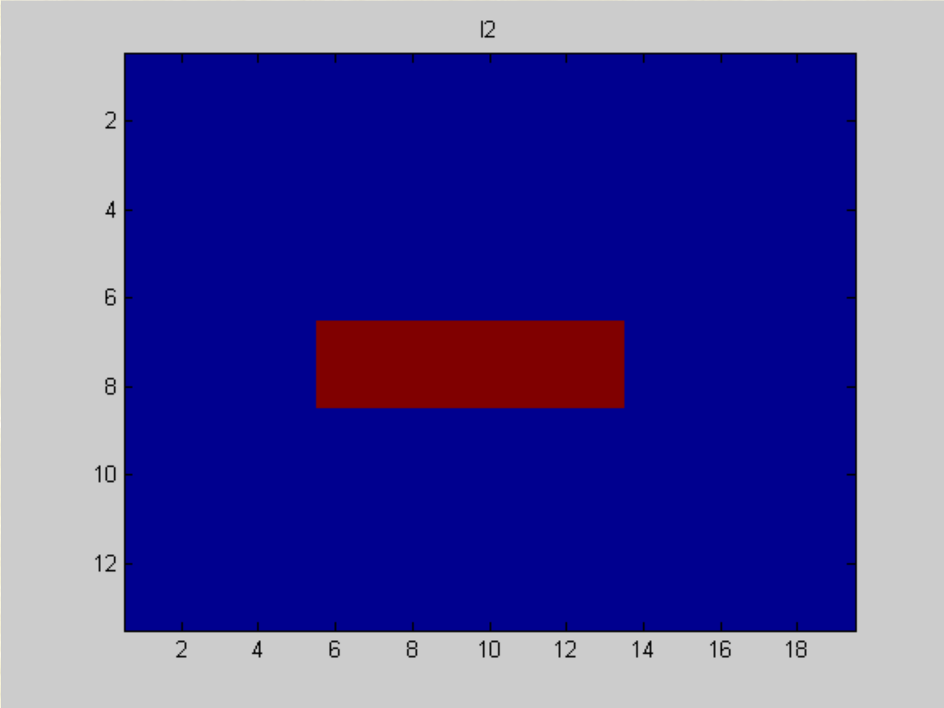
(MATLAB) code



SE = 3x3



I2

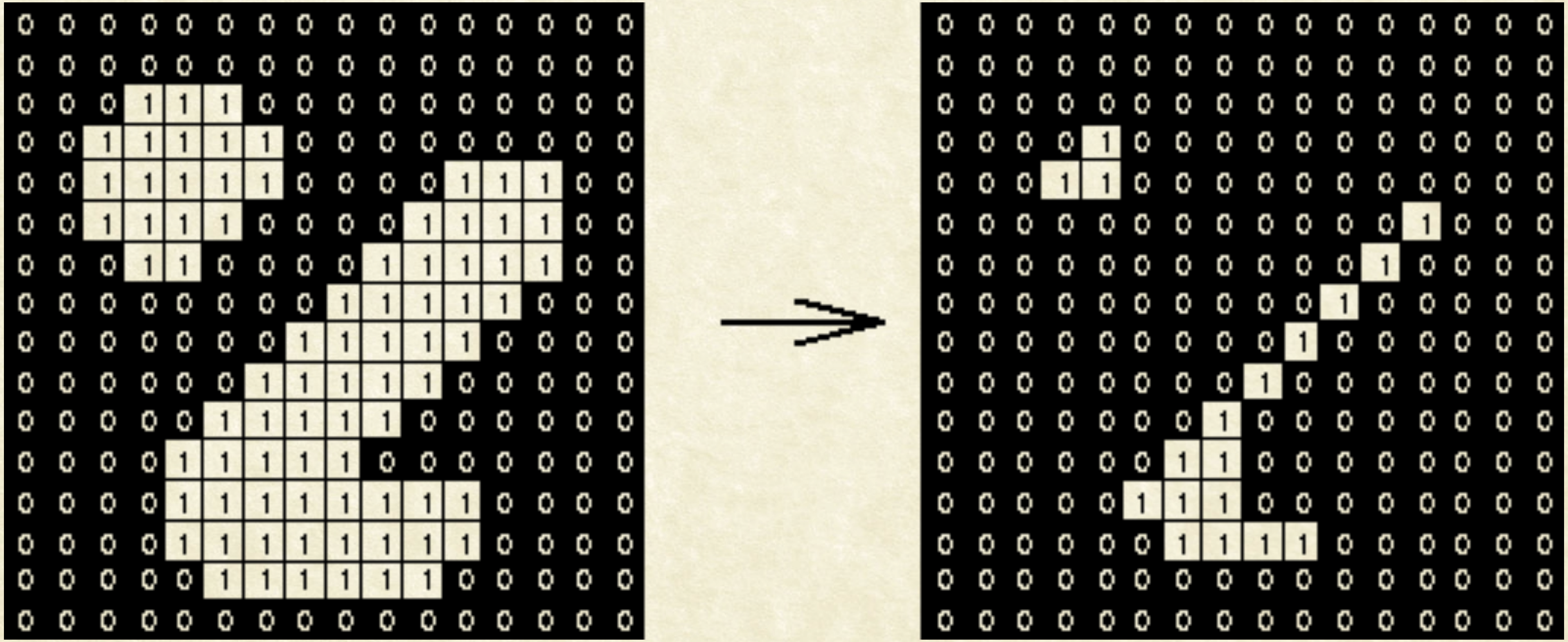


I3 = imerode(I2, SE);

Erosion

1	1	1
1	1	1
1	1	1

- Simple application of **pattern matching**



Dilation operation (max filter)

1	1	1
1	1	1
1	1	1

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

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

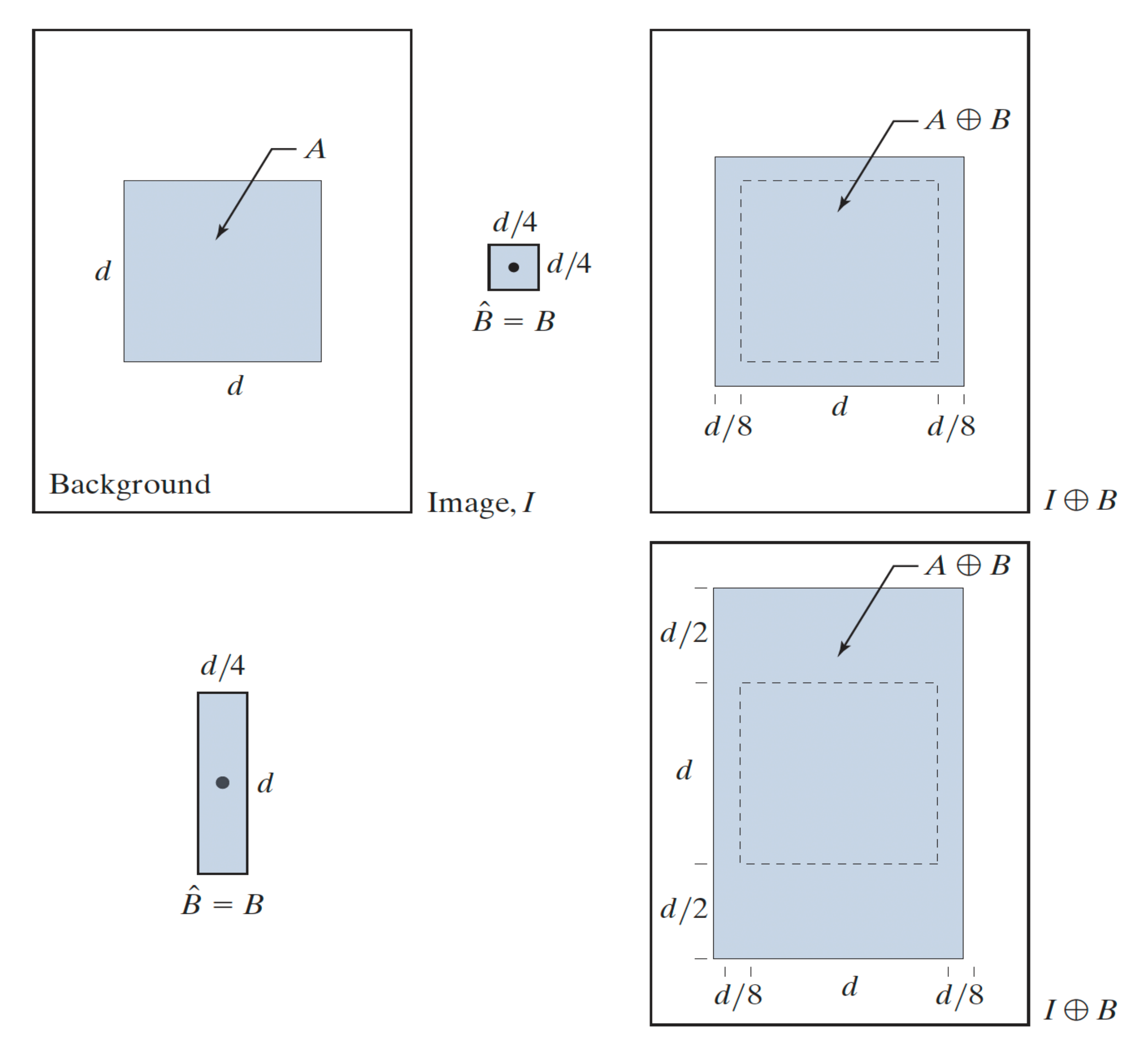
Dilation: Effect of Structuring Element

$$A \oplus B = \left\{ z \middle| \left[(\hat{B})_z \cap A \right] \neq \emptyset \right\}$$

The shape of SE decides the directions of addition of foreground pixels

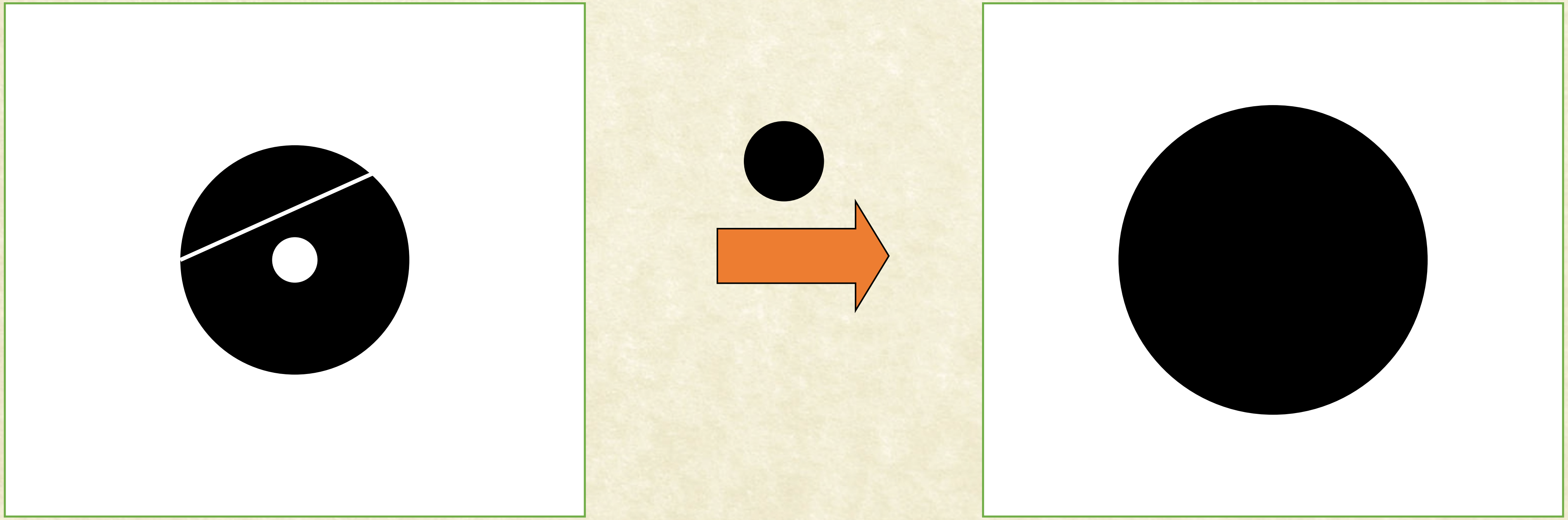
Alternately:

$$A \oplus B = \left\{ z \middle| \left[(\hat{B})_z \cap A \right] \subseteq A \right\}$$

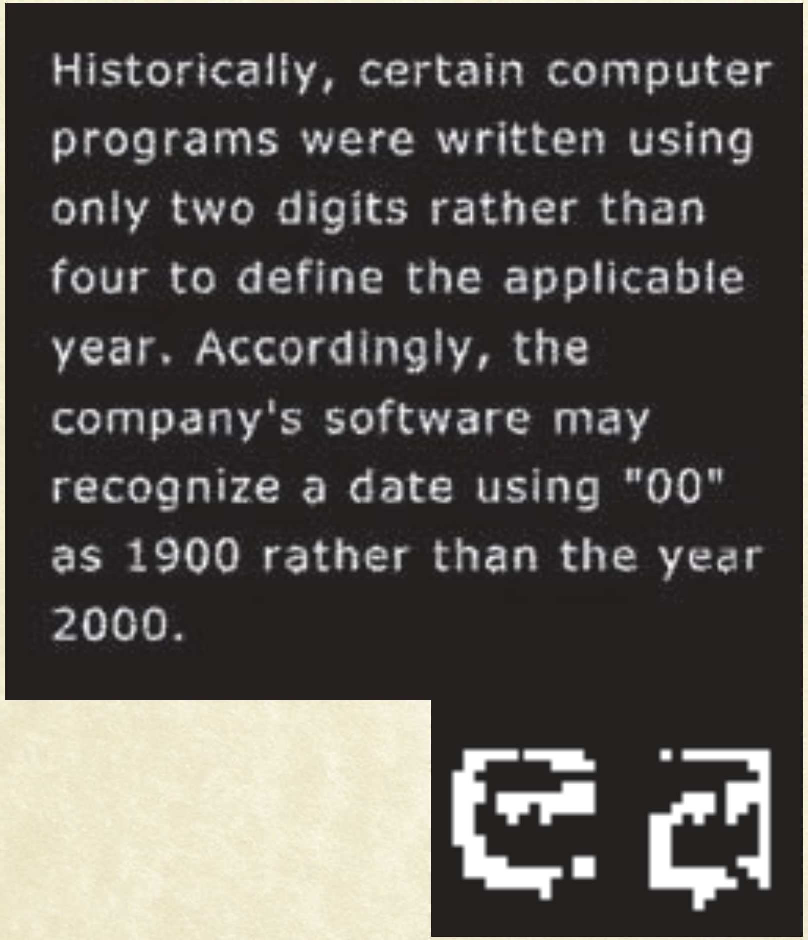


Dilation

- Expands foreground objects
- Foreground holes are shrunk / removed
- Broken objects are connected
- NOTE: Multiple iterations of dilation

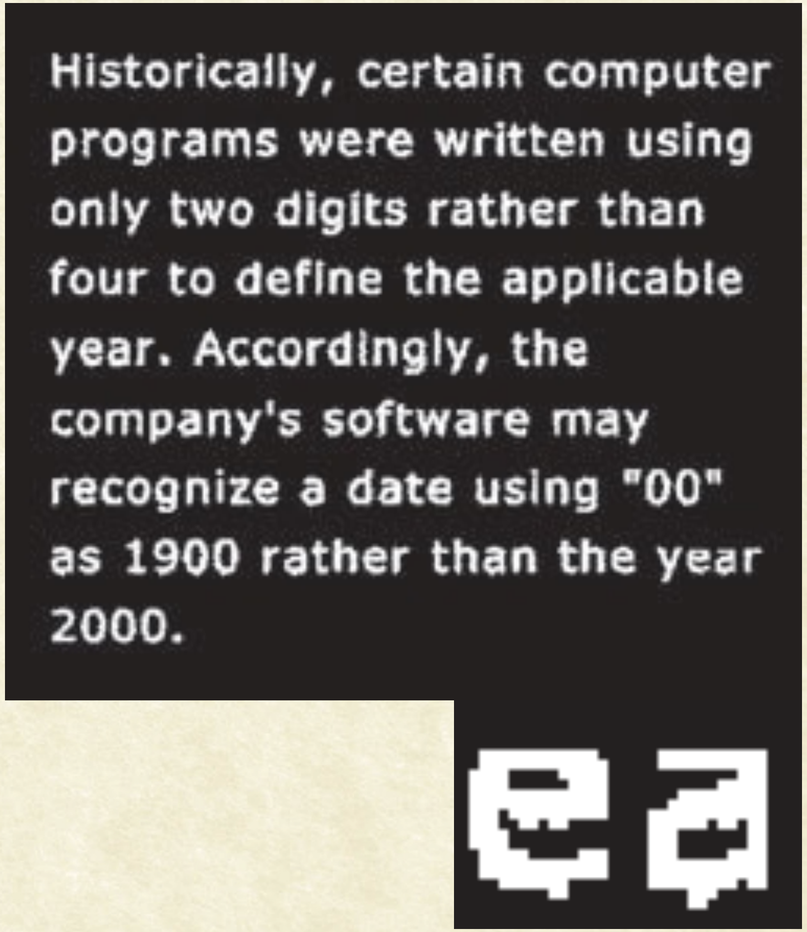


Dilation: Application



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.

1	1	1
1	1	1
1	1	1



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.

Duality of Erosion and Dilation

- Erosion and dilation are duals of each other with respect to set complementation and reflection.

$$(A \ominus B)^c = A^c \oplus \hat{B}$$

$$(A \oplus B)^c = A^c \ominus \hat{B}$$

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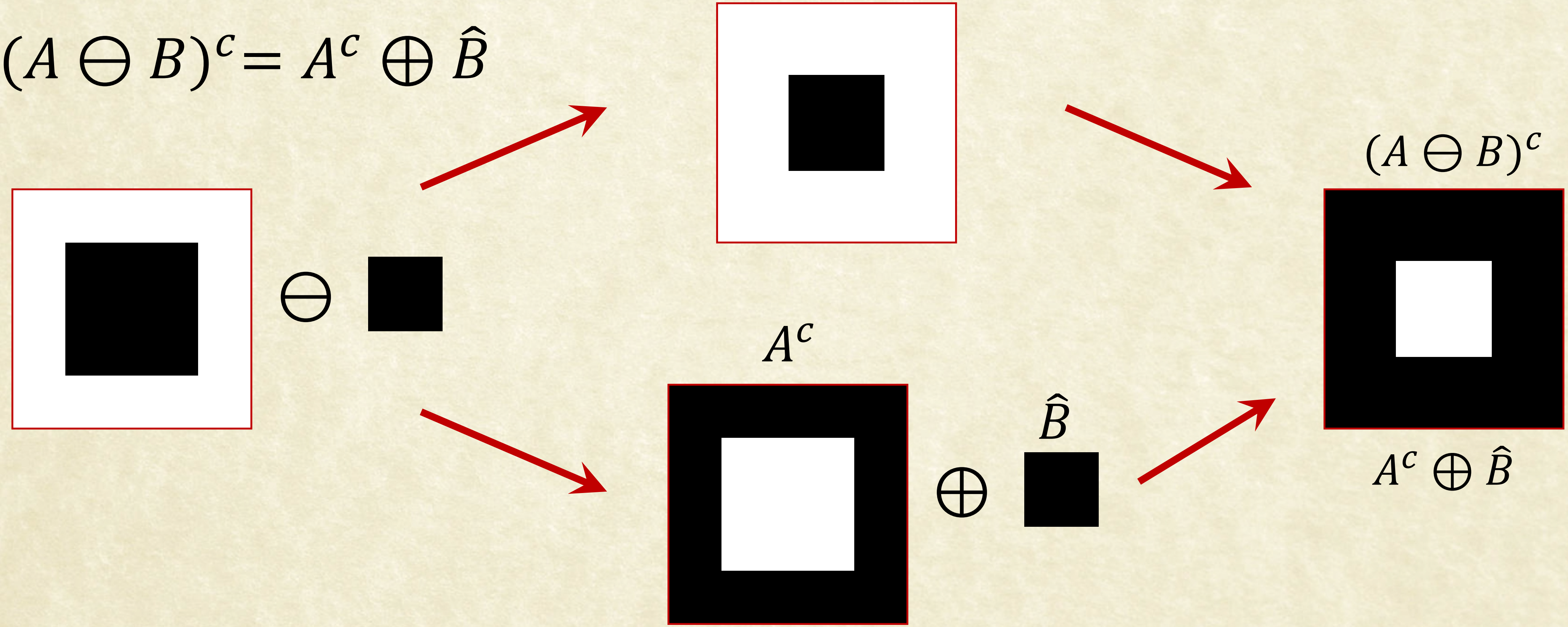

Duality of Erosion and Dilation

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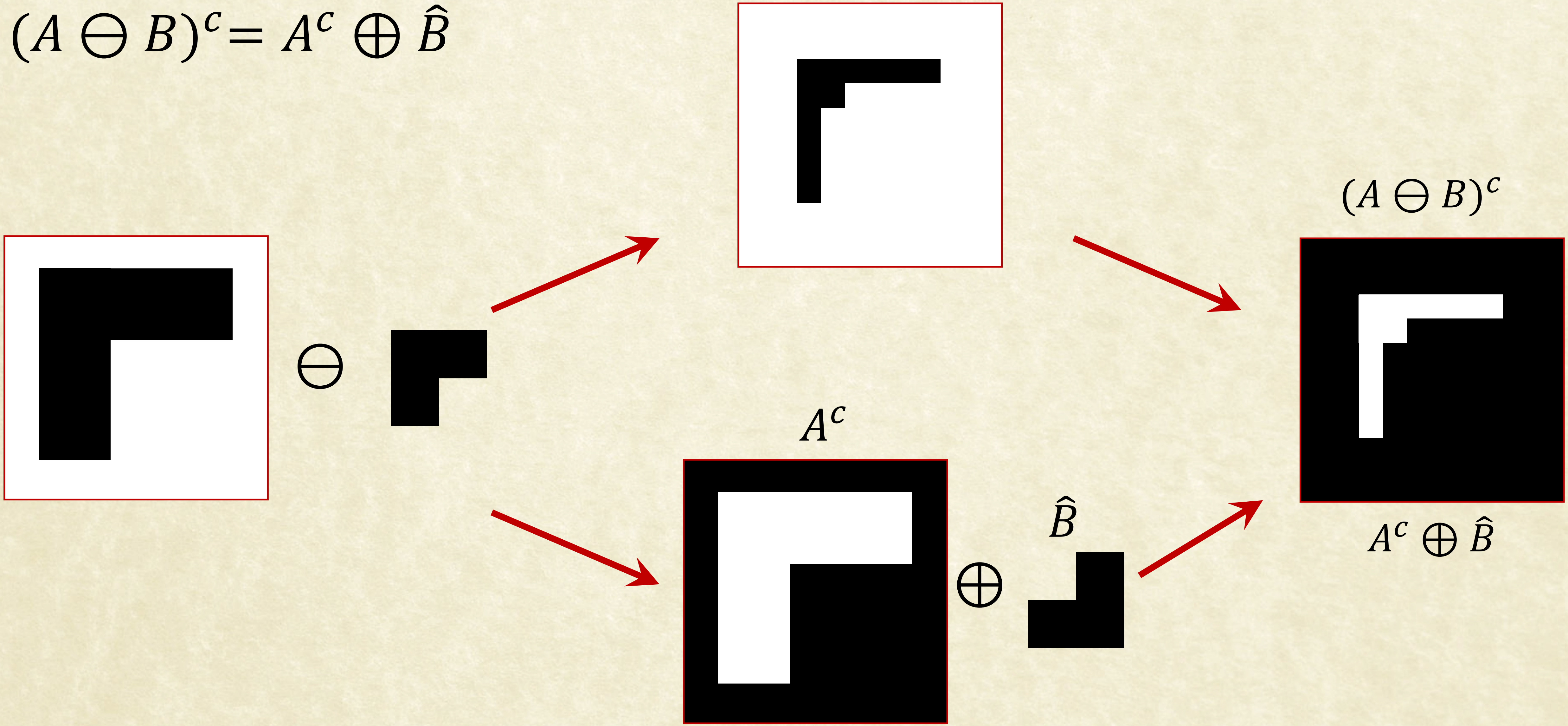


Duality: Proof

- By definition: $A \ominus B = \{z | (B)_z \subseteq A\} = \{z | (B)_z \cap A^c = \emptyset\}$
- Therefore: $(A \ominus B)^c = (\{z | (B)_z \cap A^c = \emptyset\})^c$
- Note: Complement of the set z satisfying $(B)_z \cap A^c = \emptyset$ is the set z that satisfies $(B)_z \cap A^c \neq \emptyset$.
- Therefore: $(A \ominus B)^c = \{z | (B)_z \cap A^c \neq \emptyset\}$
- i.e., $\boxed{(A \ominus B)^c = A^c \oplus \hat{B}}$ $\blacksquare$

$$\boxed{A \oplus B = \left\{z | \left[(\hat{B})_z \cap A\right] \neq \emptyset\right\}}$$

Opening and Closing

- We would like to maintain the size of objects while filling holes or removing connections

- Opening: Erode, then Dilate

$$A \circ B = (A \ominus B) \oplus B$$

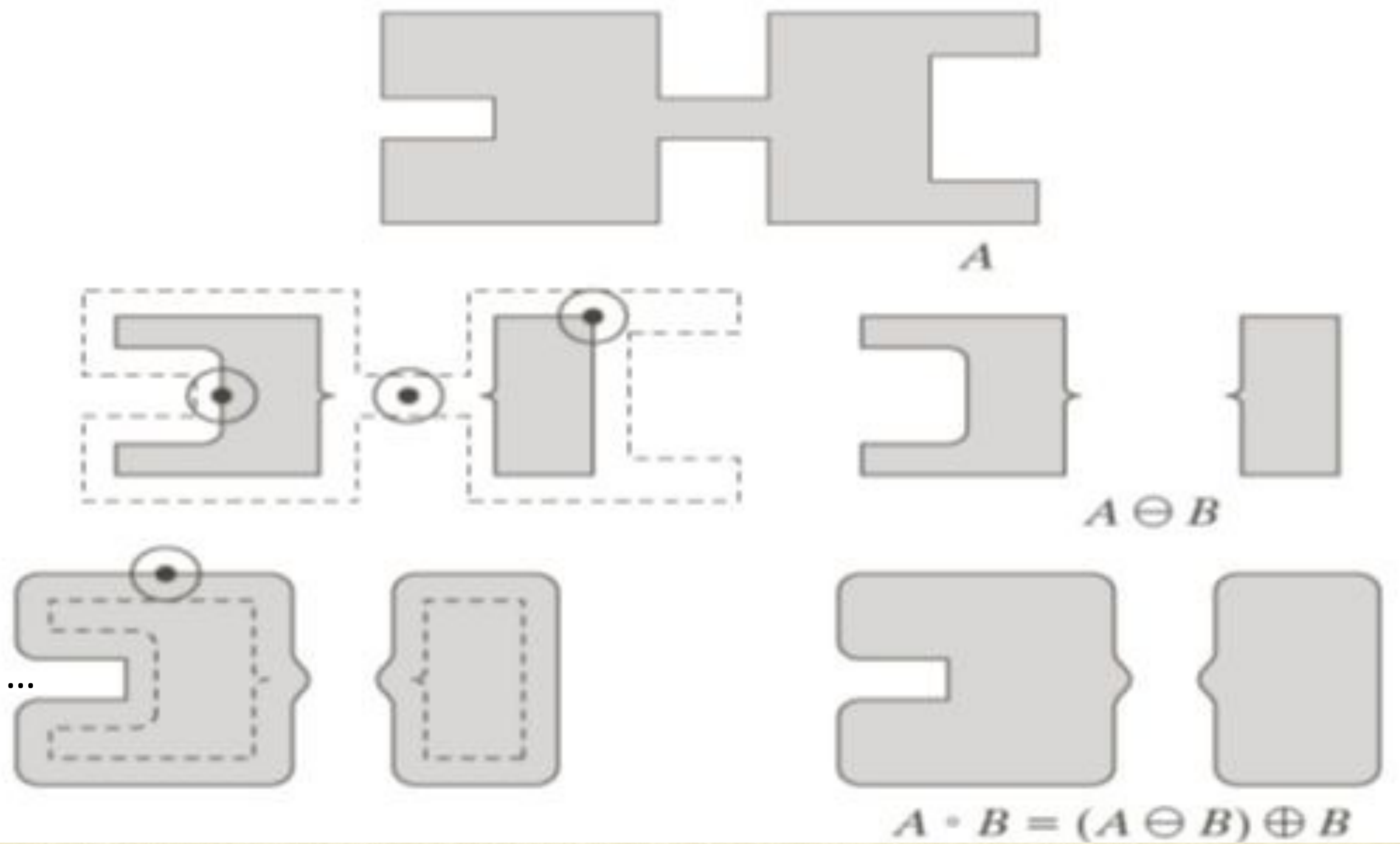
- Closing: Dilate, then Erode

$$A \cdot B = (A \oplus B) \ominus B$$

Opening:

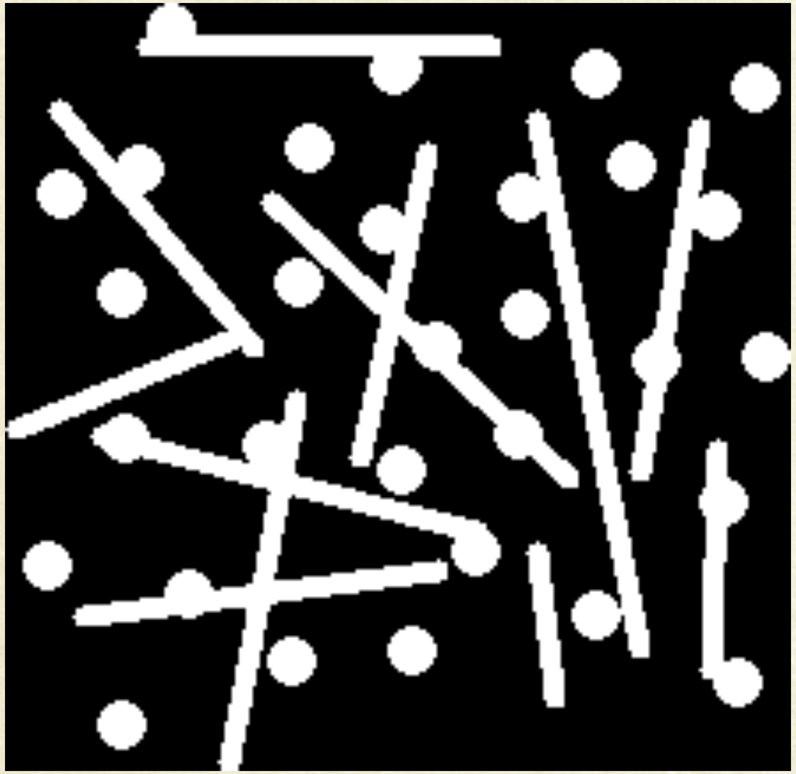
Erosion

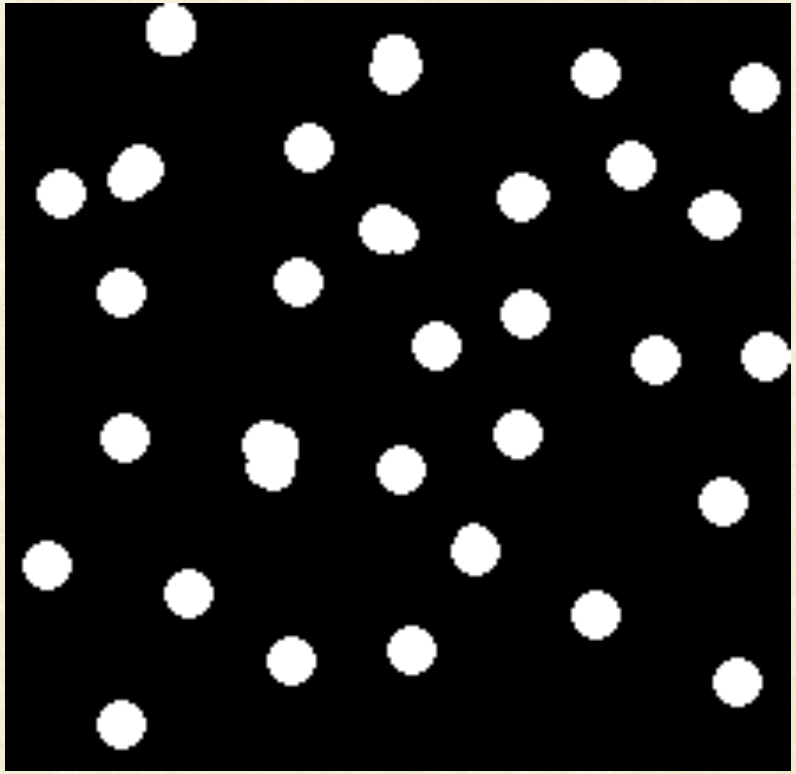
Followed by dilation …



Opening: Example

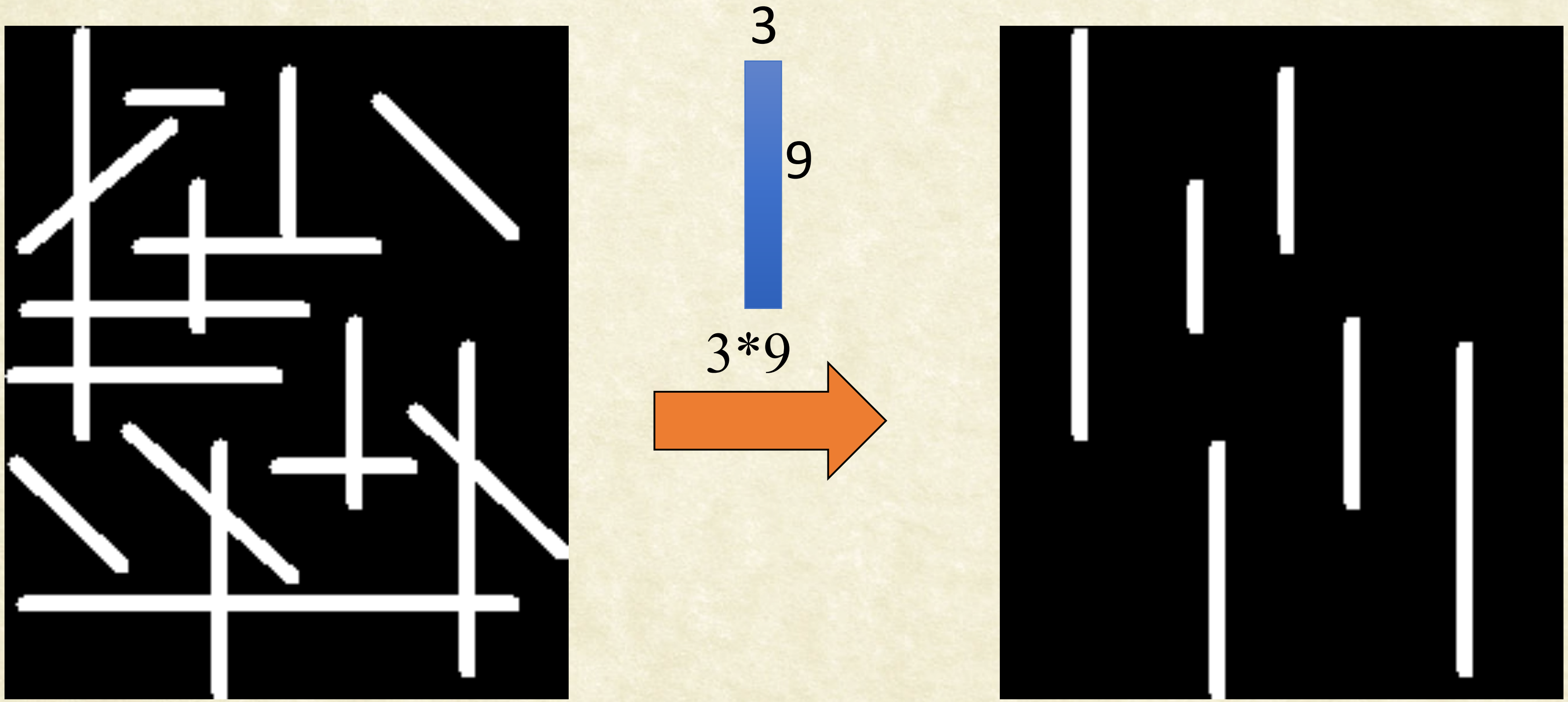
- Opening with a 11 pixel diameter disc





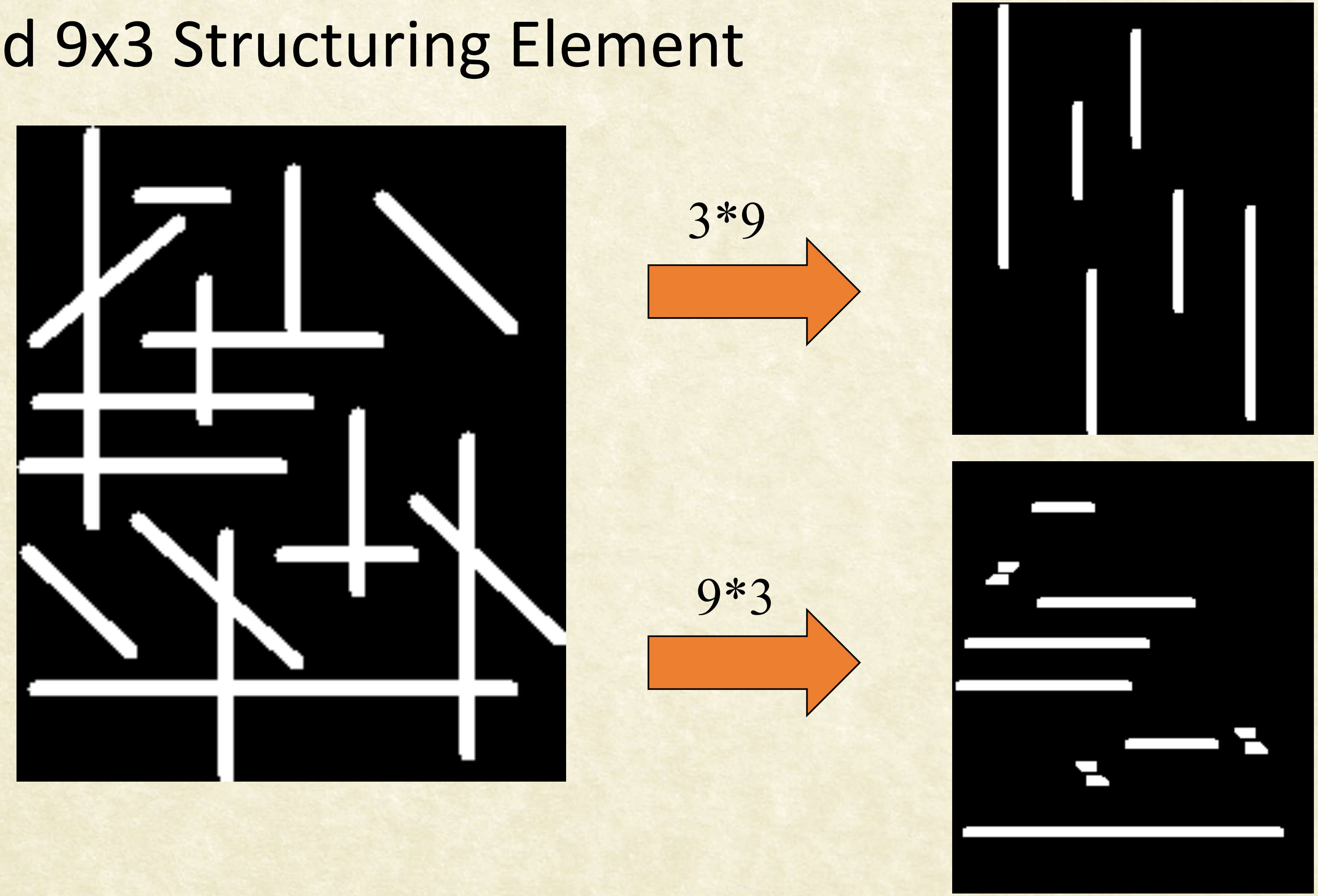
Opening: Another Example

- 3x9 Structuring Element



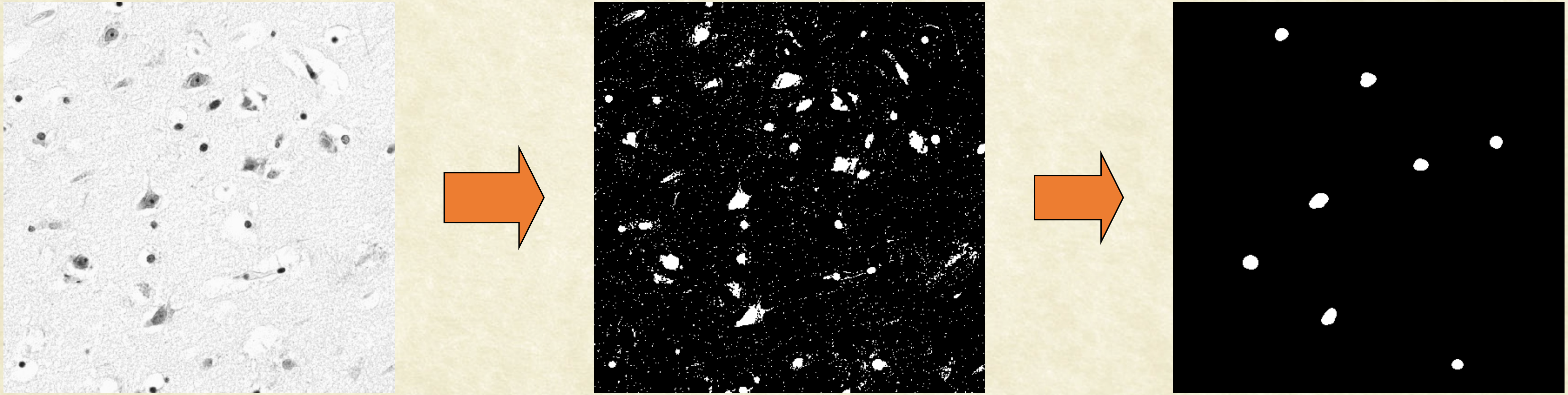
Opening: Another Example

- 3x9 and 9x3 Structuring Element



Use Opening for Separating Blobs

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

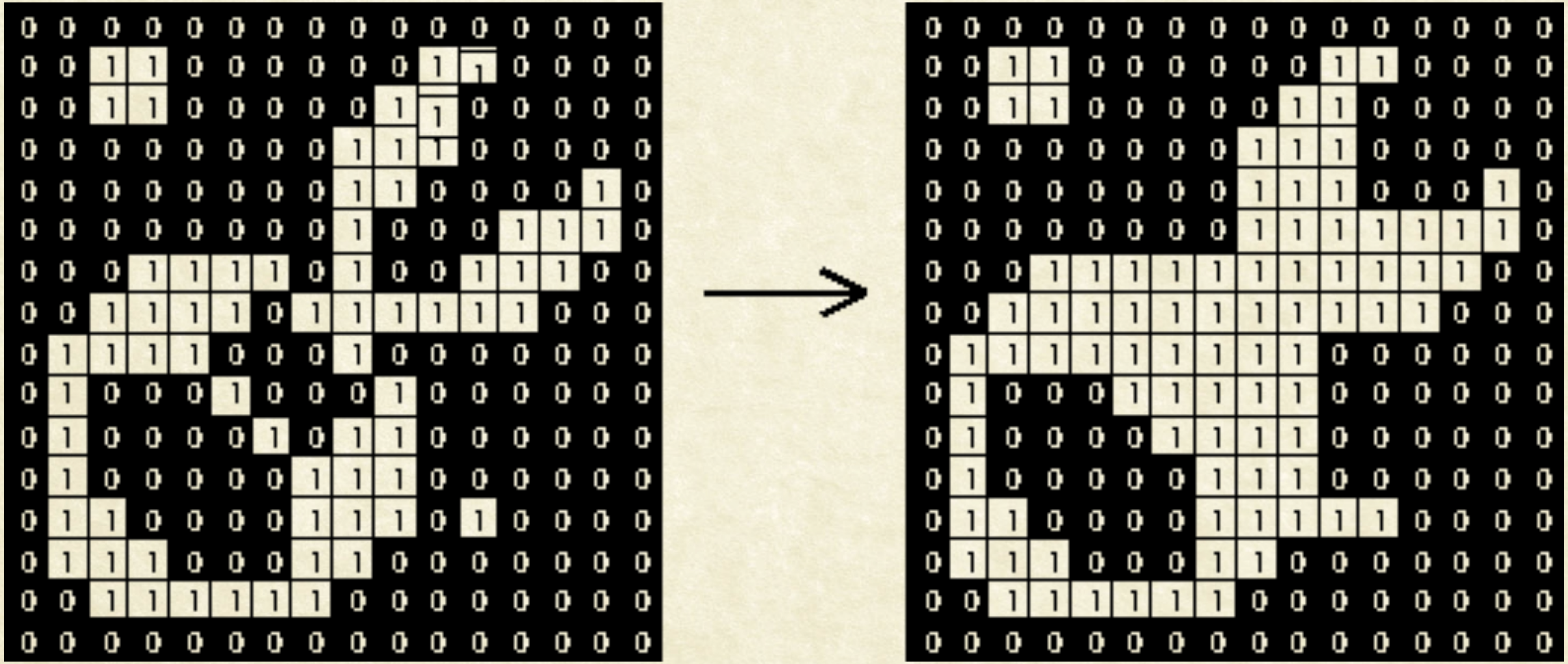


Opening

- Similar to Erosion
  - Spot and noise removal
  - Less destructive
- Erosion followed by Dilation
- *Same structuring element for both operations.*
- Opening is **idempotent**
  - Repeated application has no further effects!

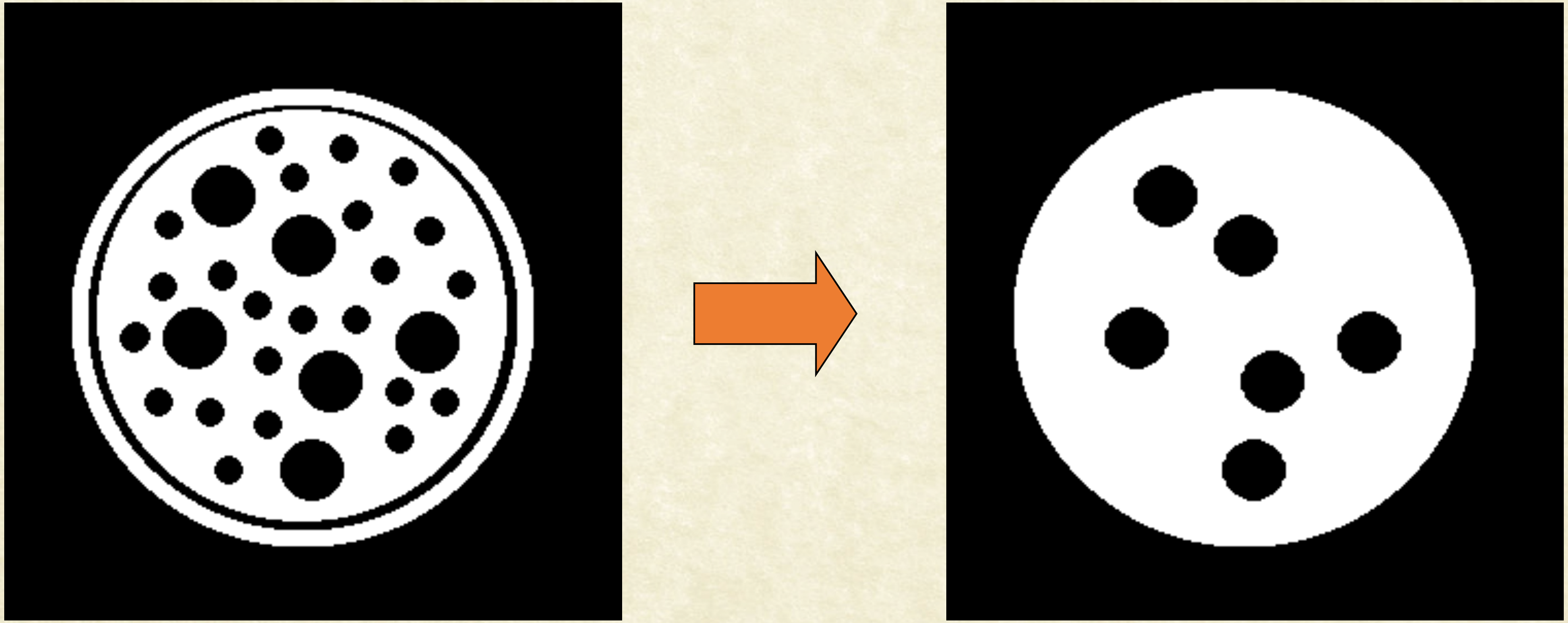
Closing (Dilation then Erosion)

- Structuring element: 3x3 square



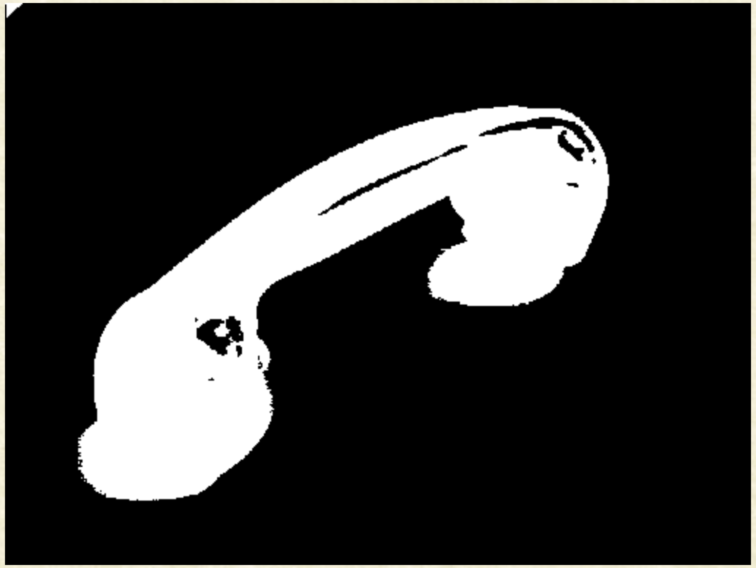
Closing: Example

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

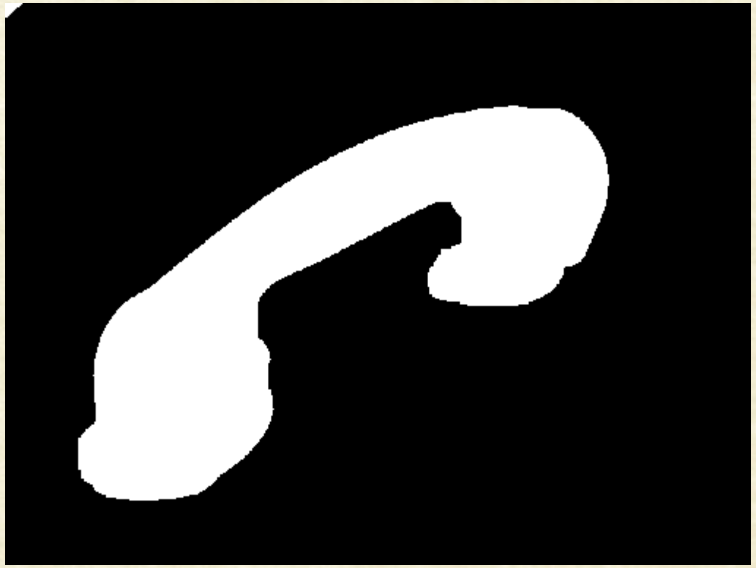


Closing Example

1. Threshold
2. Closing with disc of size 20



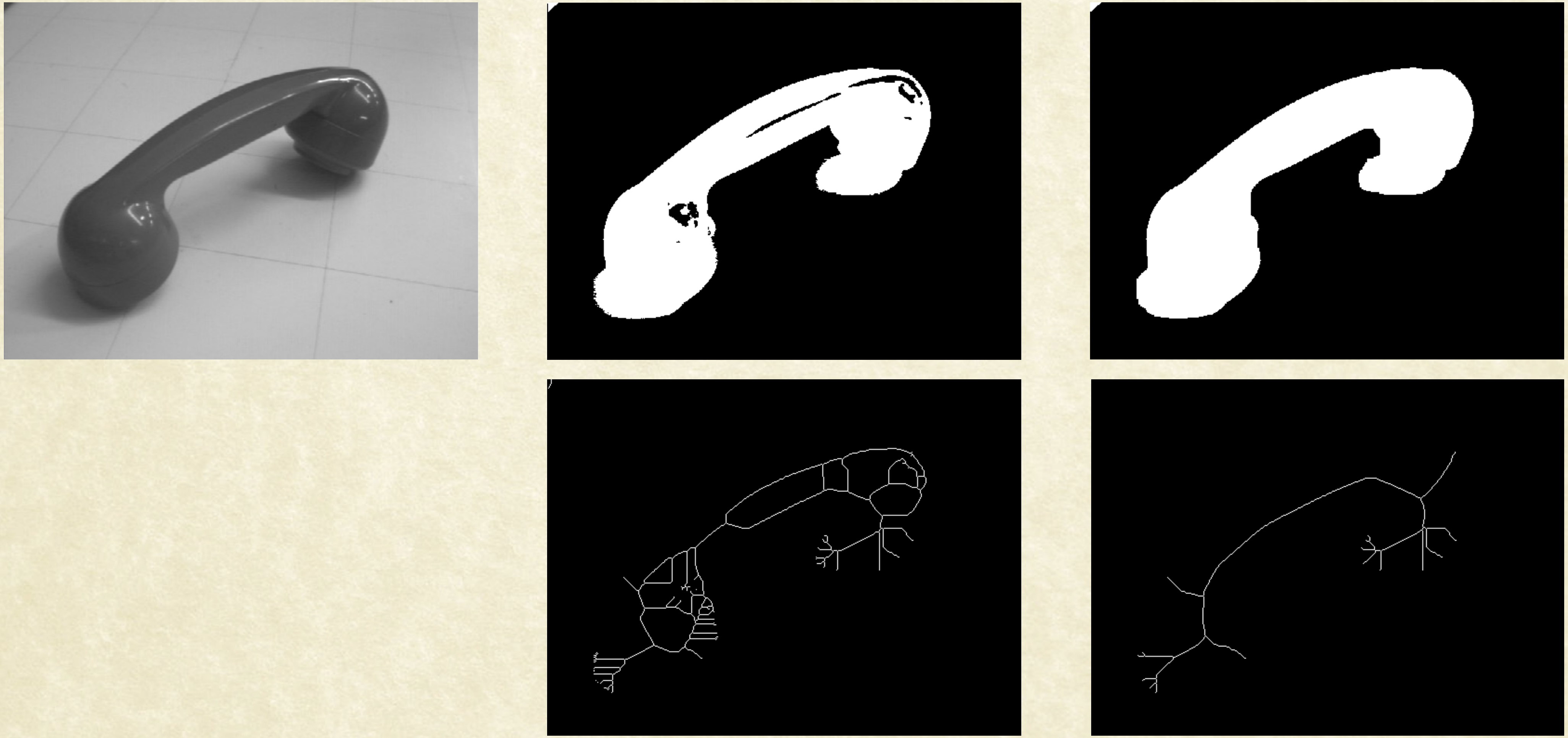
Thresholded



Closed

Application of Closing

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



Questions?