Morphological Image Processing

Image Processing

CSE 166

Lecture 13

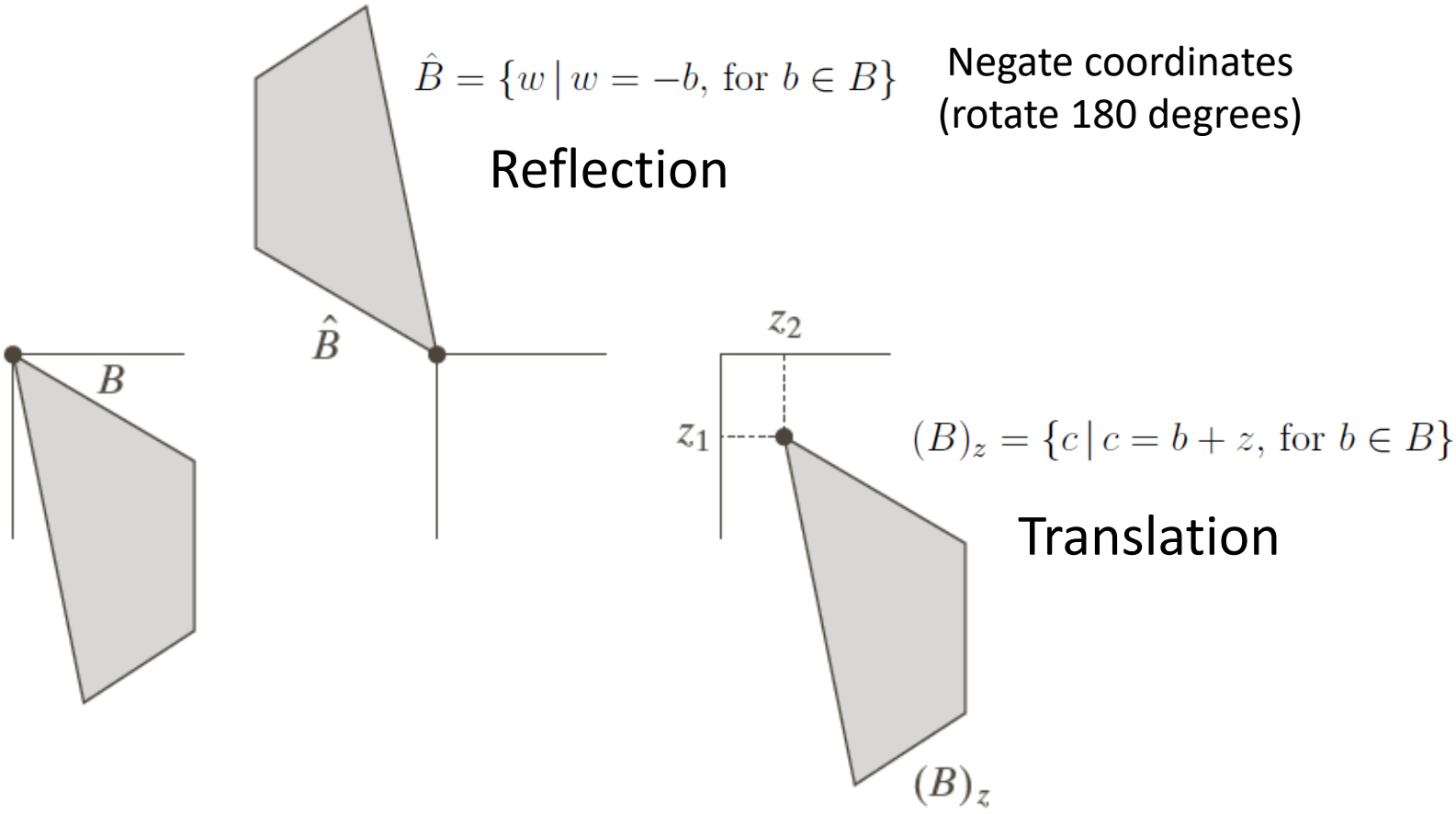
Announcements

- Assignment 5 is due today, 11:59 PM
- Assignment 6 will be released today
  - Due Mar 8, 11:59 PM
- Reading
  - Chapter 9: Morphological image processing
    - Sections 9.1, 9.2, 9.3, and 9.5 (through subsection connected components)

Morphological image processing

- Mathematical morphology
- Set theory
- Binary image

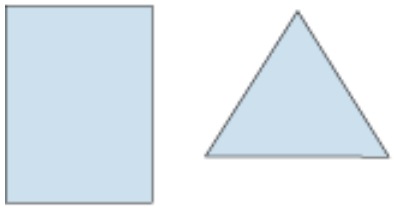
Reflection and translation



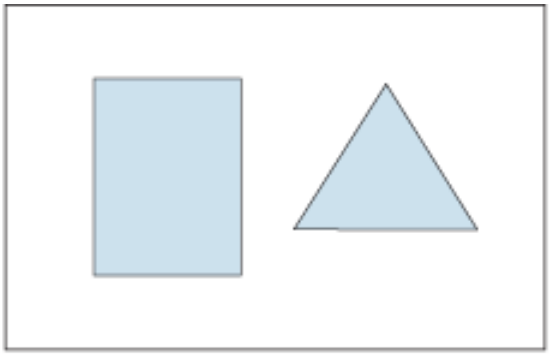
Structuring elements

- Small sets used to probe an image
  - Origin is commonly in the center of the structuring element (similar to spatial filtering kernels)

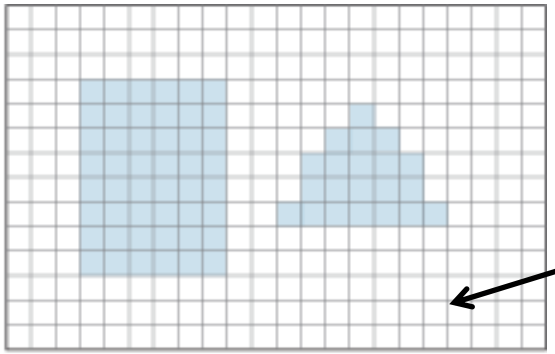
Sets of pixels: objects and structuring elements (SEs)



Objects representeed as sets



Objects represented as a graphical image



Digital image

Border of background pixels around objects

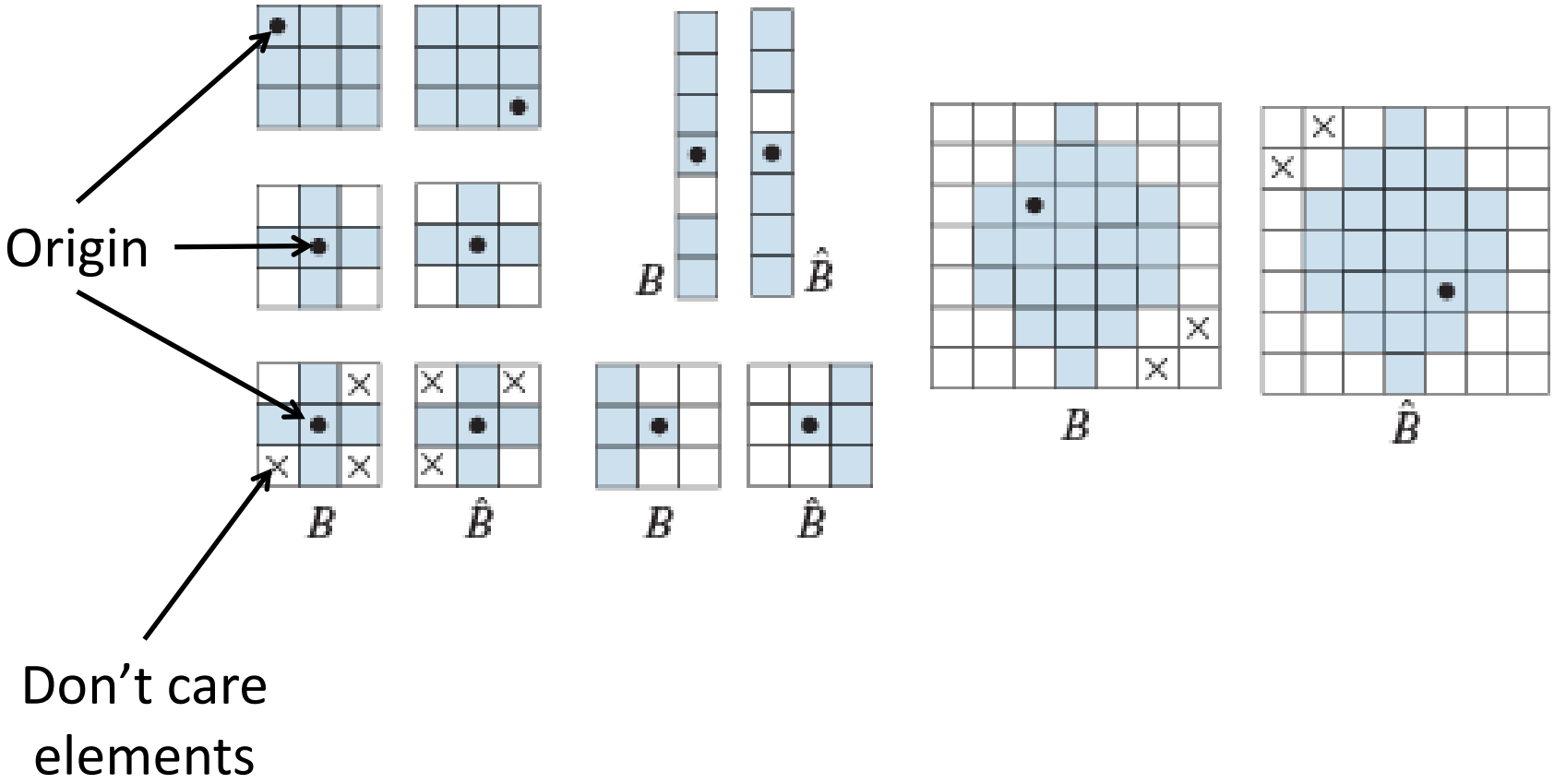
Structuring element represented as a set

Structuring element represented as a graphical image

Digital structuring element

Tight border around SE

Reflection about the origin



Morphological operations

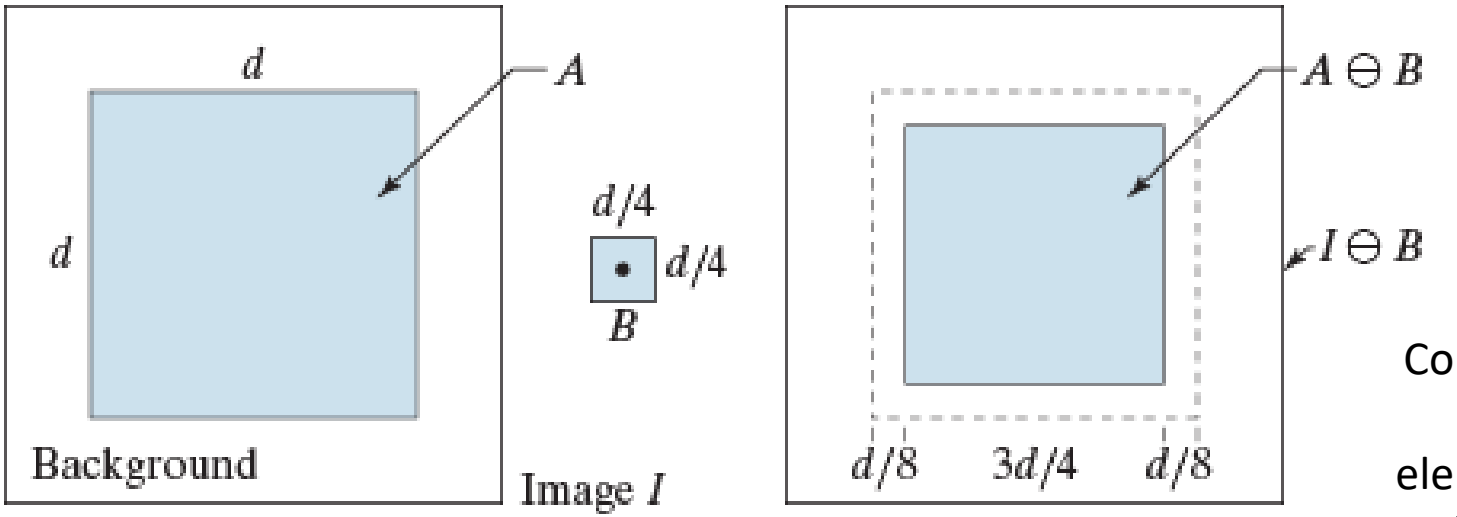
- Erosion
- Dilation
- Opening
- Closing

Erosion

- Example: square SE
  - The erosion of A by B

B translated by z, is contained in A

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



Complement of A (i.e., set of elements not in A)

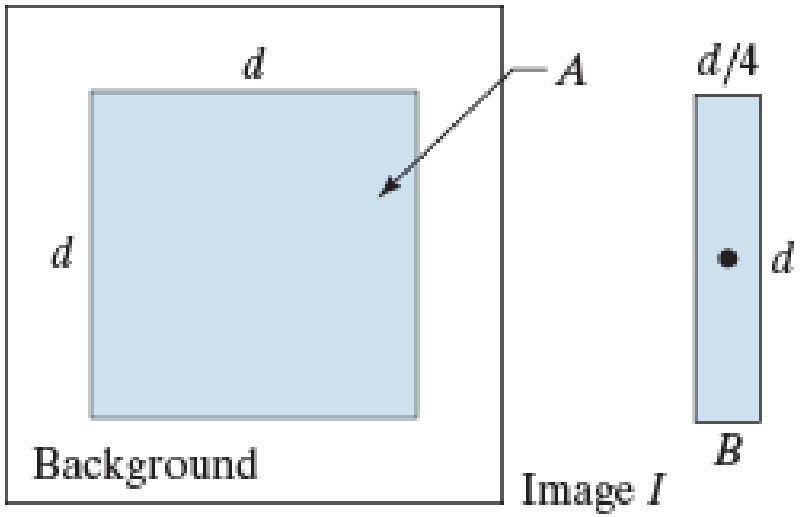
$$I \ominus B = \{z \mid (B)_z \subseteq A \text{ and } A \in I\} \cup \{A^c \mid A^c \subseteq I\}$$

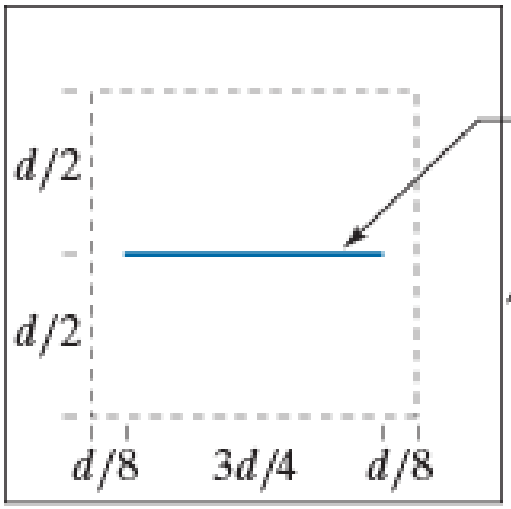
Erosion

- Example: elongated SE
  - The erosion of A by B

B translated by z, is contained in A

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



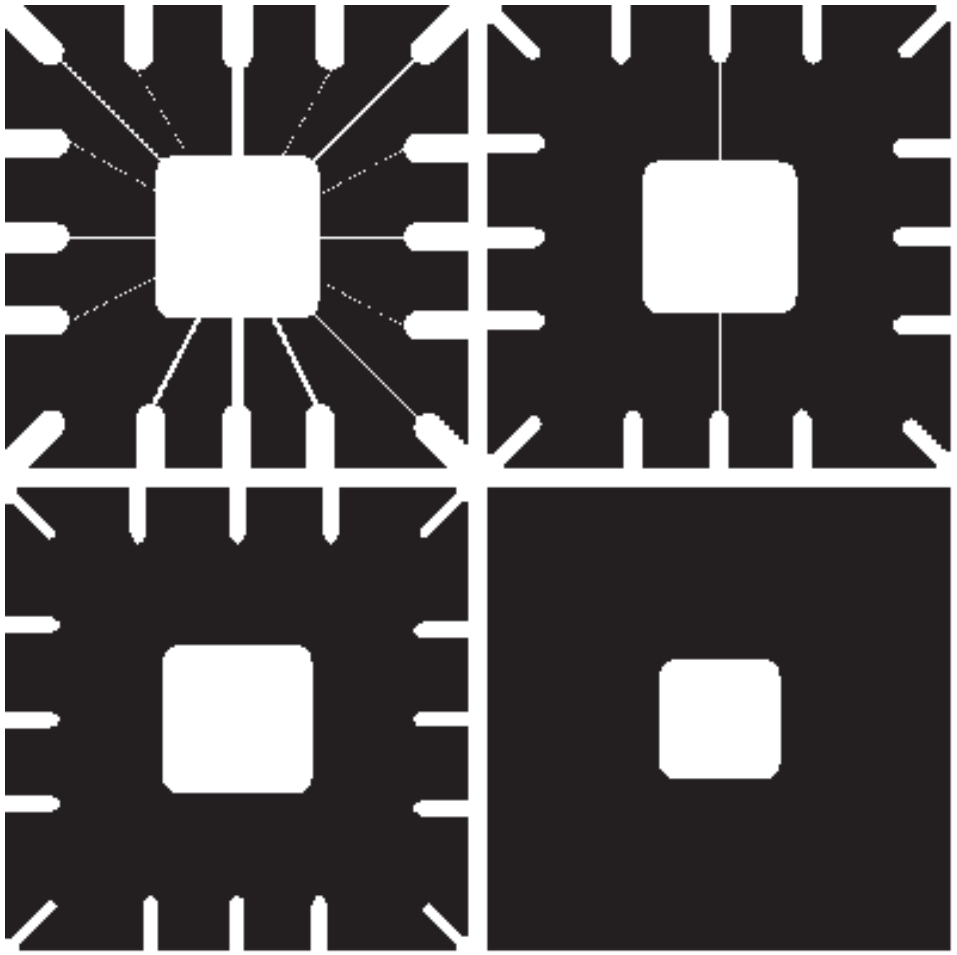


Complement of A (i.e., set of elements not in A)

$$I \ominus B = \{z \mid (B)_z \subseteq A \text{ and } A \in I\} \cup \{A^c \mid A^c \subseteq I\}$$

Erosion

Equivalent to a min filter
Shrinks



11x11

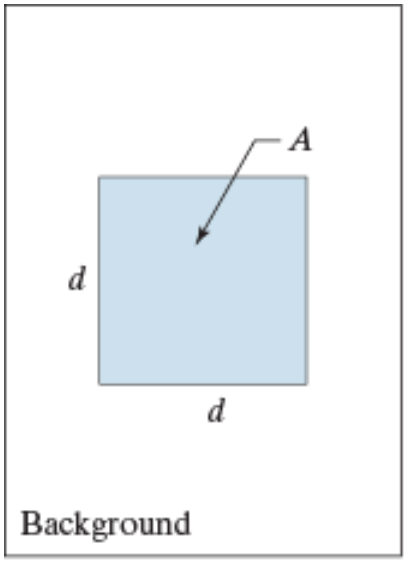
15x15

45x45

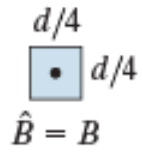
Dilation

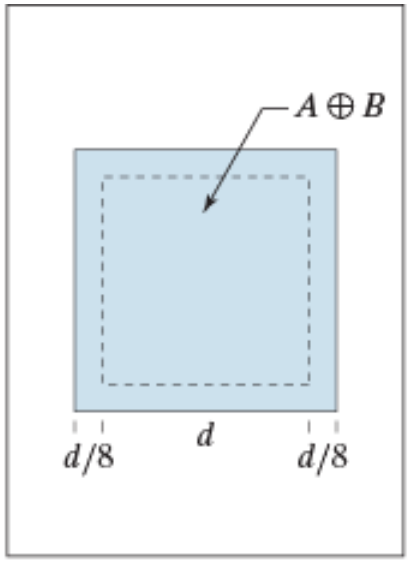
$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq \varnothing\}$$

Examples



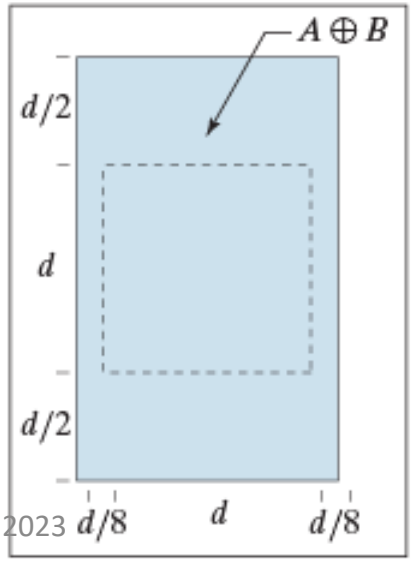
Image, I





$I \oplus B$

Square SE



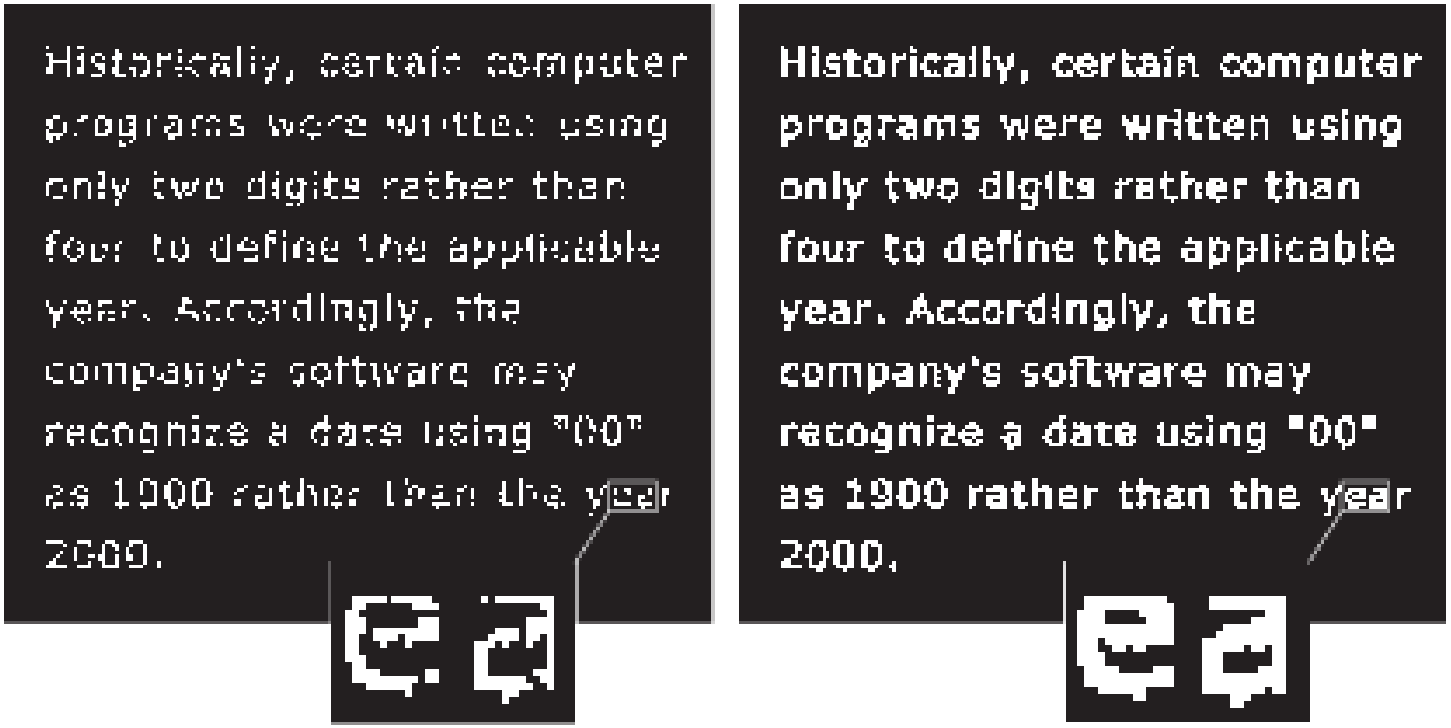
$I \oplus B$

Elongated SE

Dilation

Equivalent to a max filter

Expands



1	1	1
1	1	1
1	1	1

Duality

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

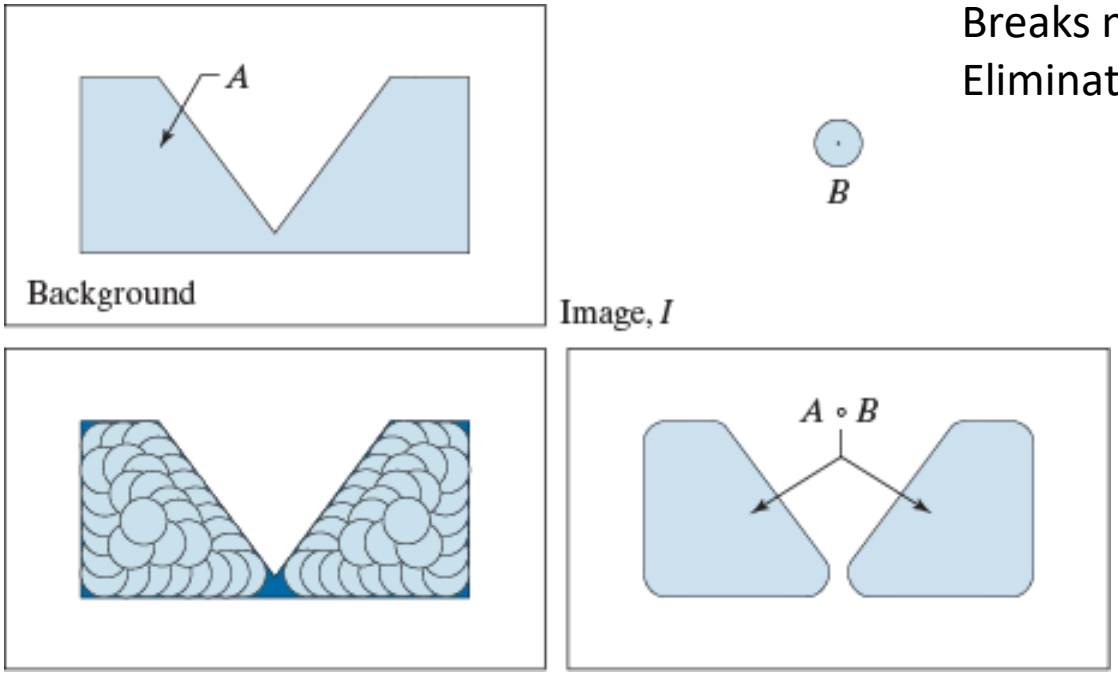
$$(A \ominus B)^c = A^c \oplus \hat{B} \text{ and } (A \oplus B)^c = A^c \ominus \hat{B}$$

Opening

- Opening a set A by structuring element B
  - Erosion followed by dilation

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

Smooths the contour of an object
Breaks narrow isthmuses
Eliminates thin protrusions

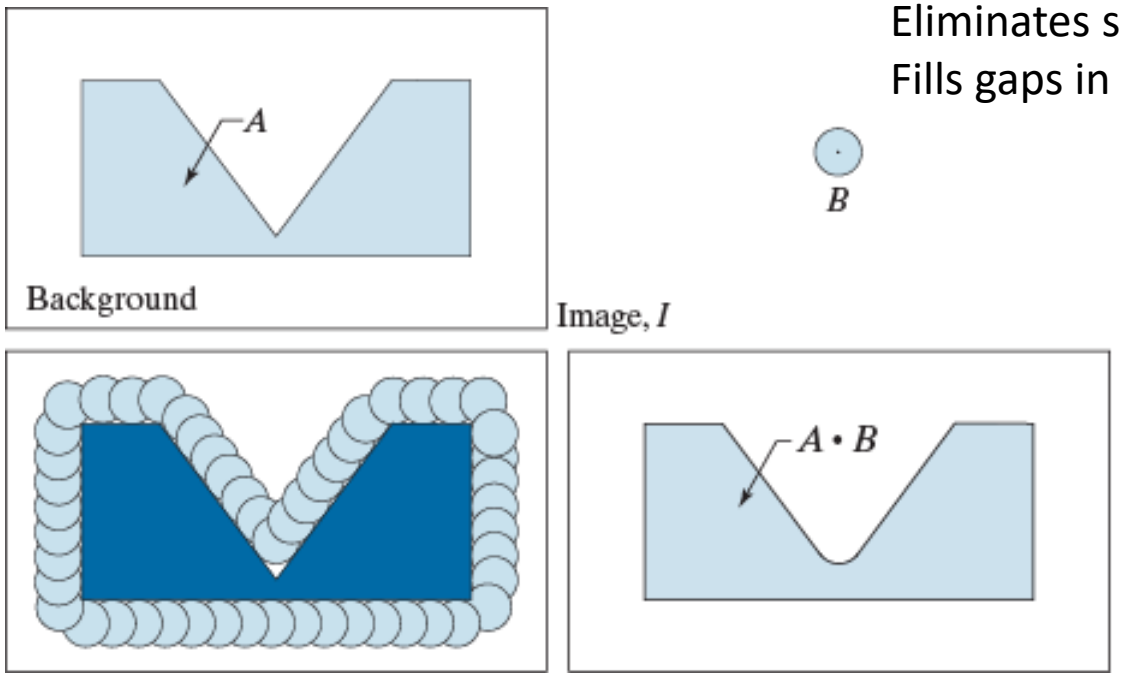


Structuring element rolls along **inner** boundary

Closing

- Closing a set A by structuring element B
  - Dilation followed by erosion $A \bullet B = (A \oplus B) \ominus B$

Fuses narrow breaks and long thin gulfs
Eliminates small holes
Fills gaps in contour of an object

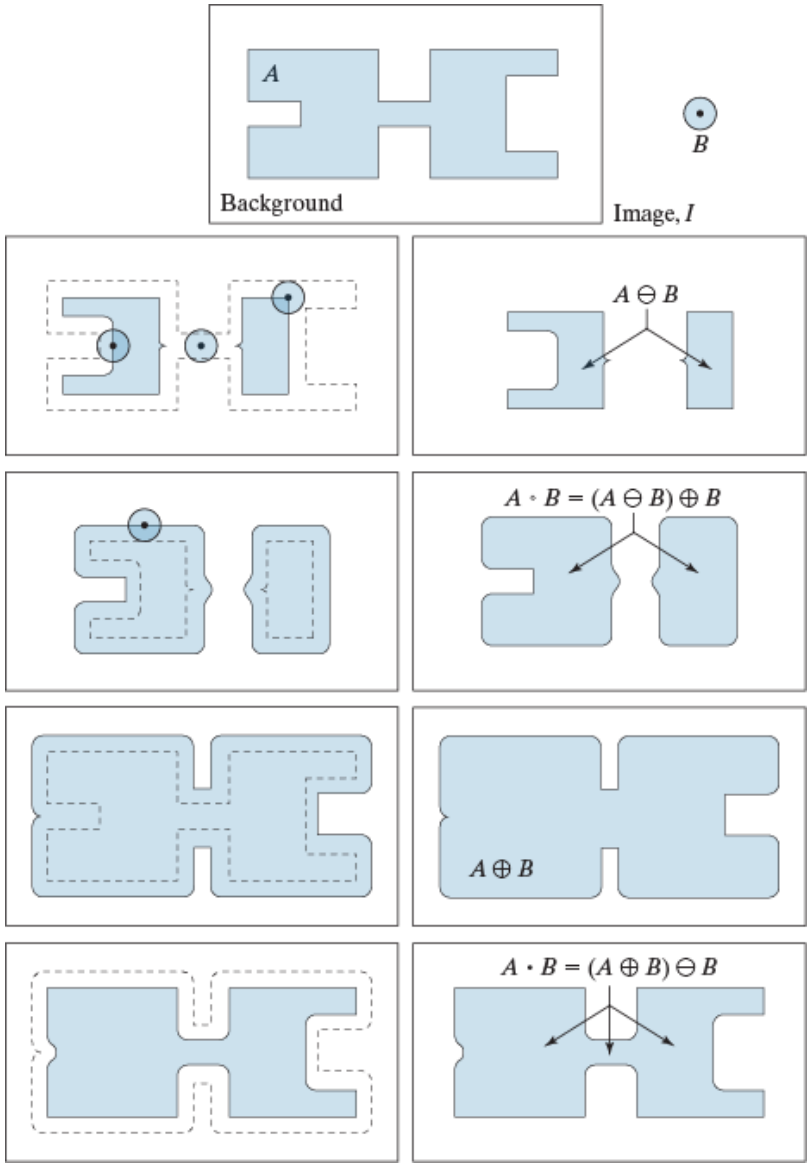


Structuring element rolls along **outer** boundary

Duality

- Opening and closing are duals of each other with respect to complementation and reflection

Basic morphological operations



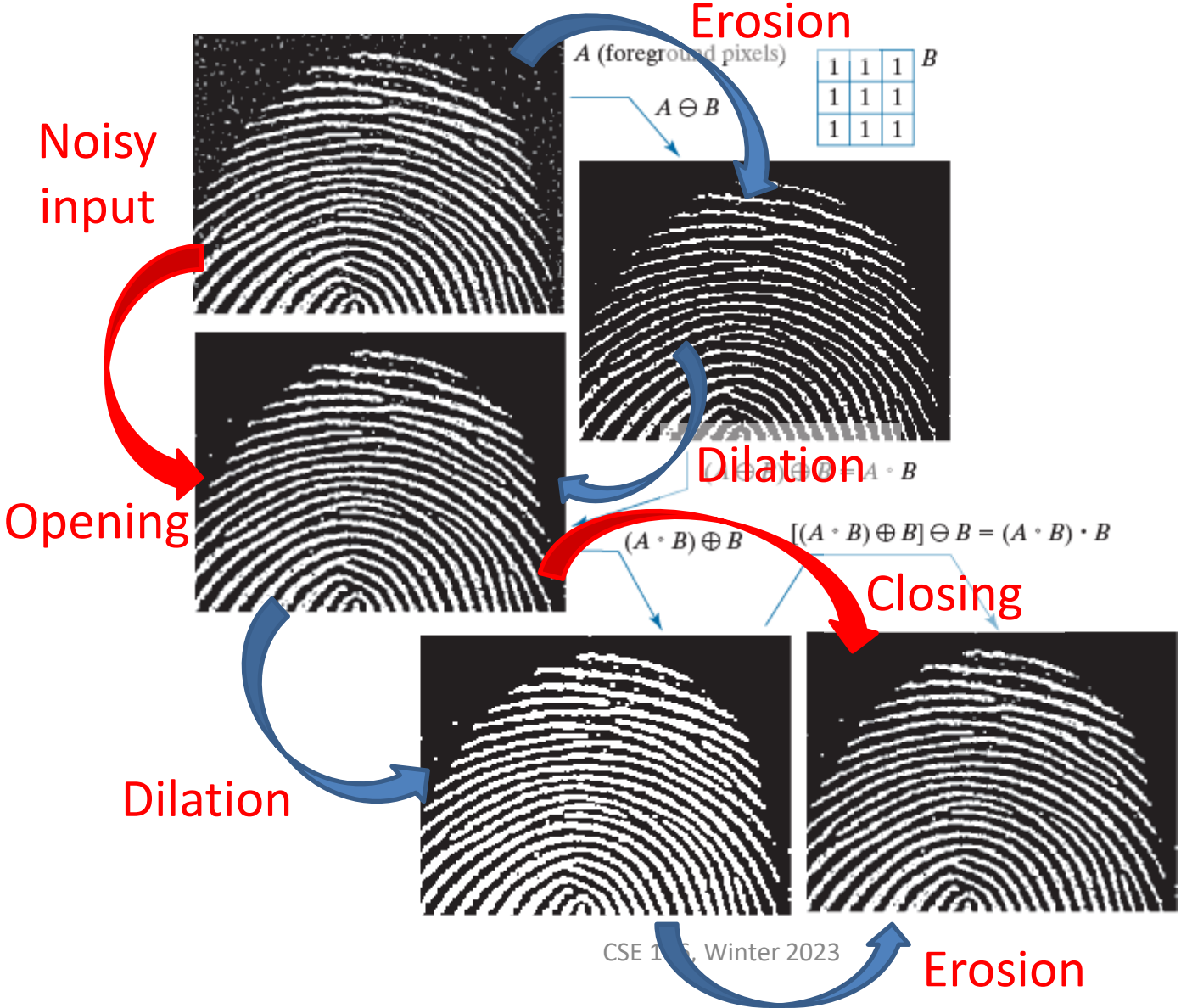
Erosion

Opening

Dilation

Closing

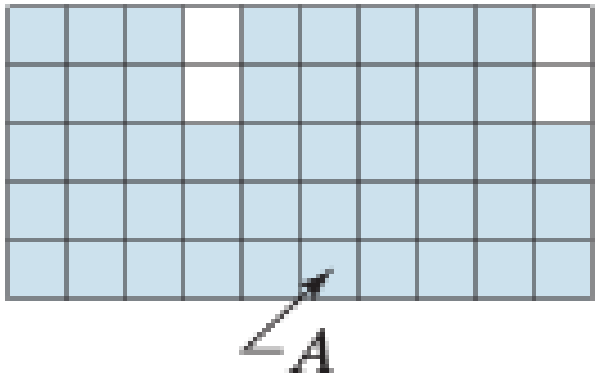
Morphological image processing

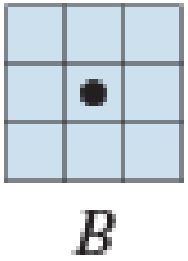


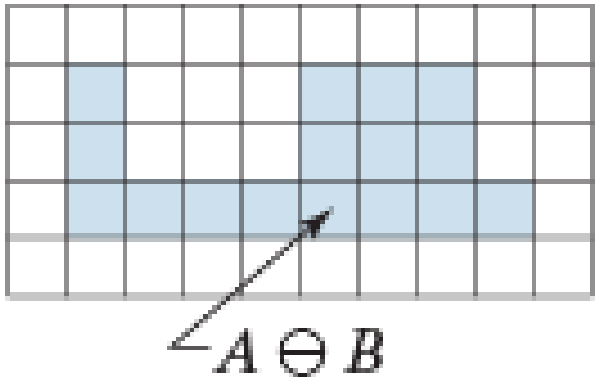
Morphological algorithms

- Boundary extraction
- Hole filling
- Connected components

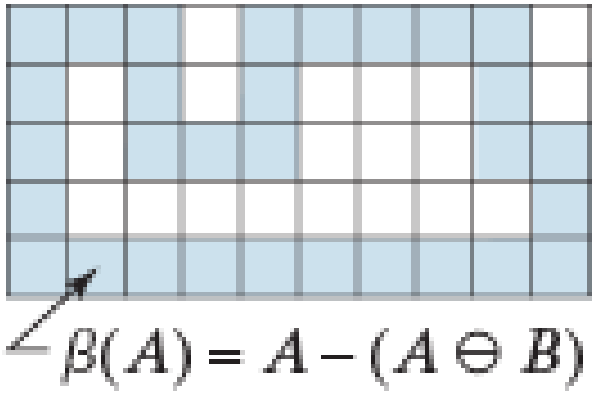
Boundary extraction





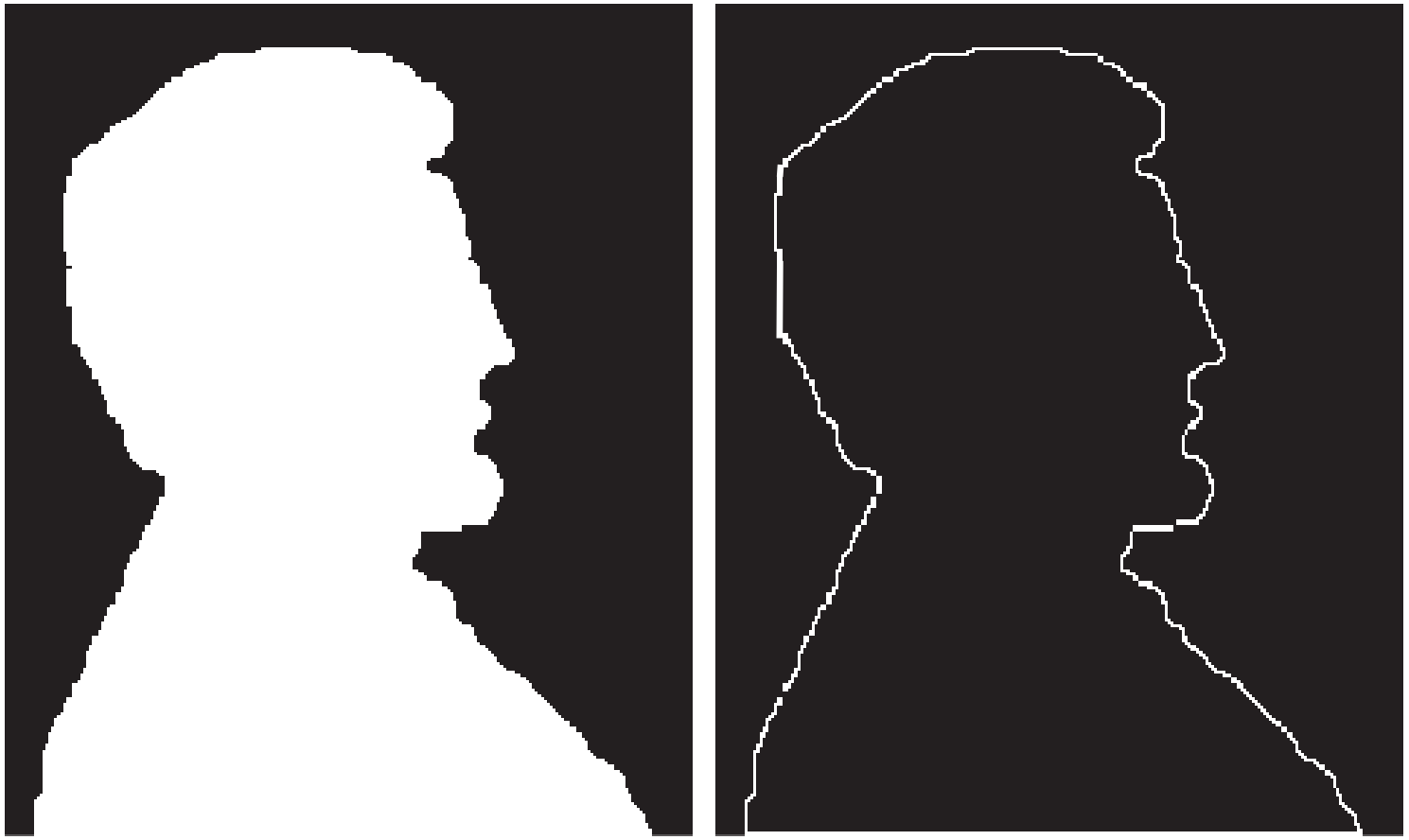


Erosion



Set difference

Boundary extraction



Hole filling

X is same size as I

X_0 is all zeros, except ones at a given point in each hole

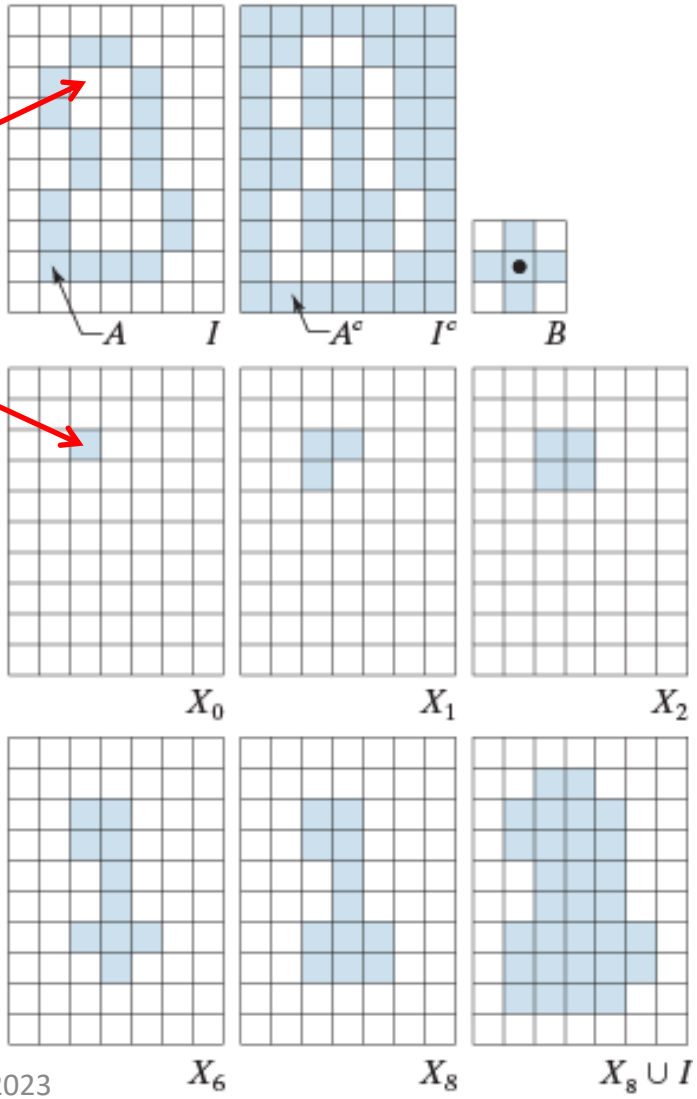
$X_k = (X_{k-1} \oplus B) \cap A^c \quad k = 1, 2, \ldots$

Looks for background points

Intersection with A^c limits dilation

Stop when $X_k = X_{k-1}$

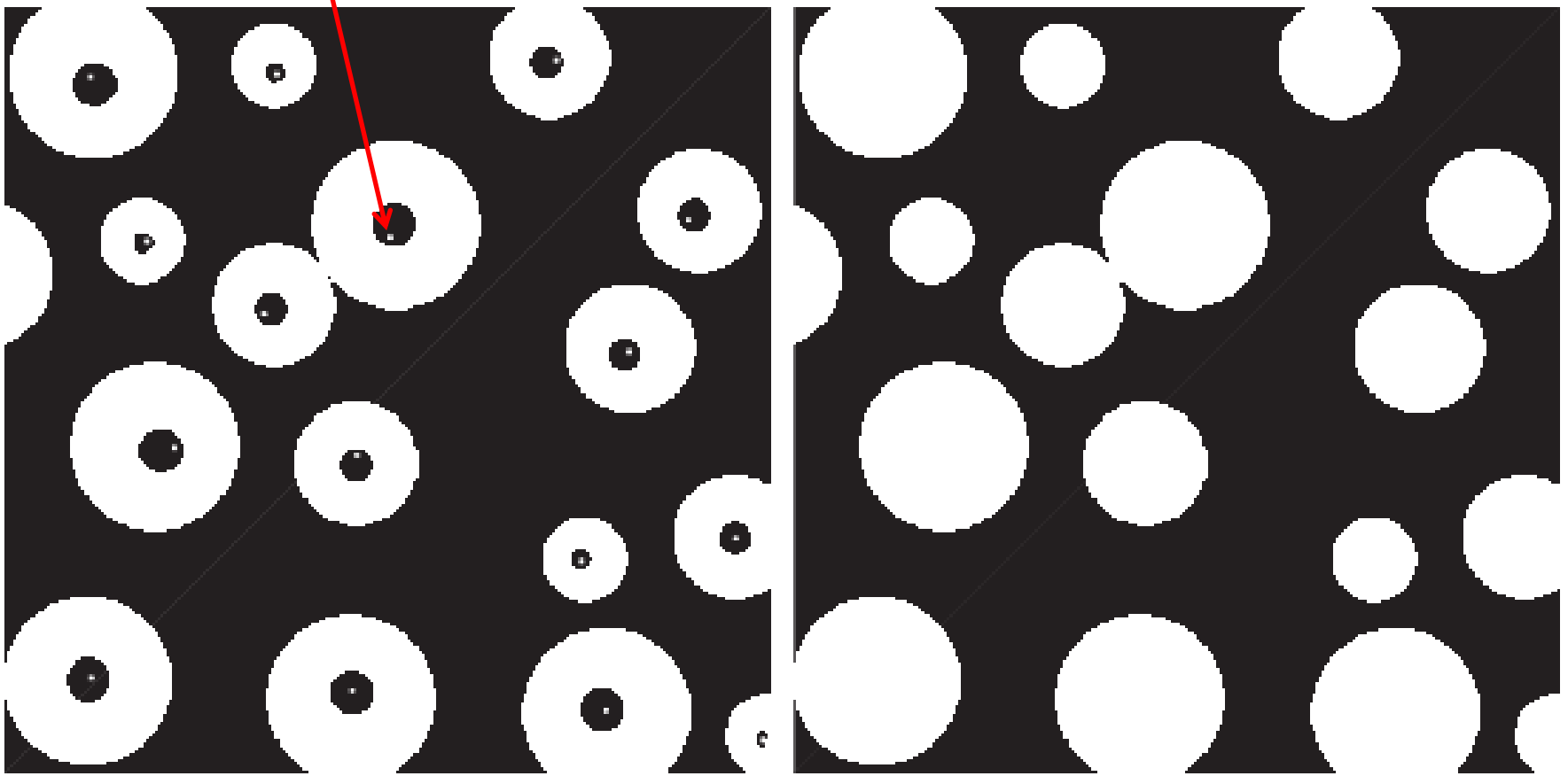
$X_{k_{\text{final}}} \cup A$ is $A$with holes filled



Hole filling

Given points in holes

All holes filled



Connected components

X is same size as I

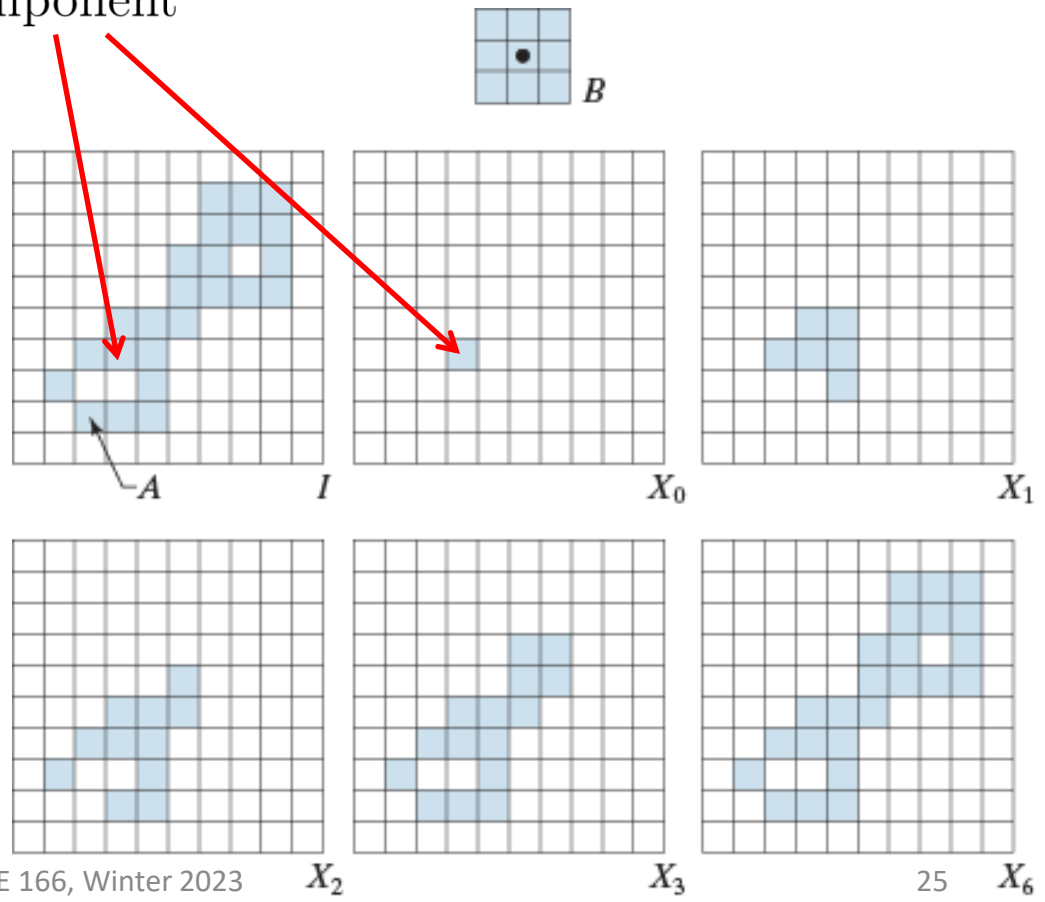
X_0 is all zeros, except ones at a
given point in each connected component

$X_k = (X_{k-1} \oplus B) \cap A \quad k = 1, 2, \ldots$

Looks for foreground points

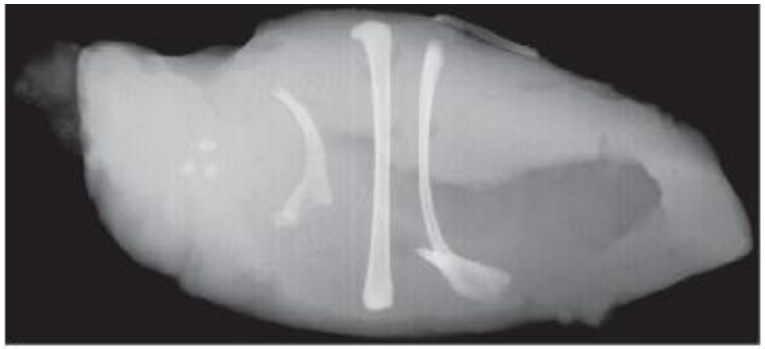
Intersection with A^c limits dilation

Stop when $X_k = X_{k-1}$

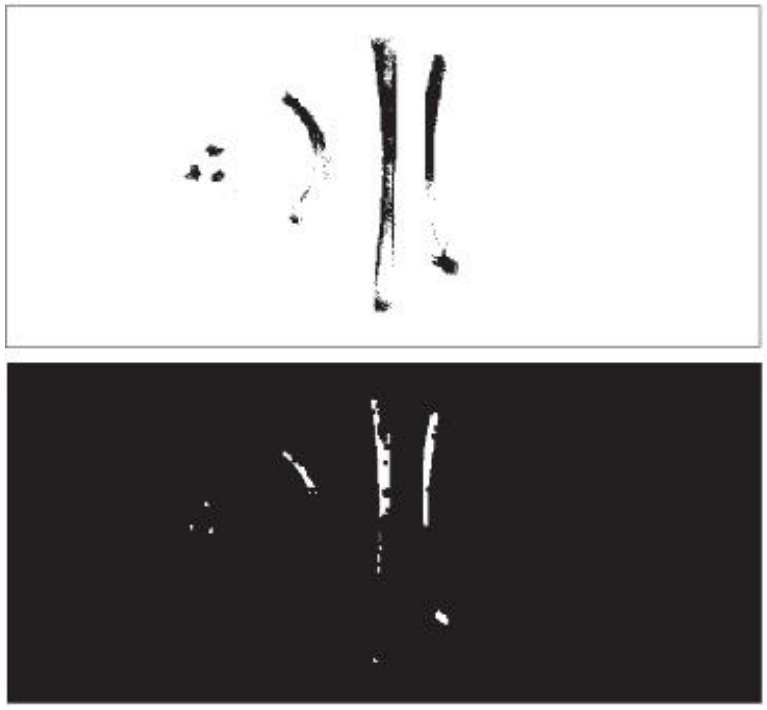


Connected components

X-ray image



Threshold (negative)



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

15 connected components

Next Lecture

- Image segmentation
- Reading
  - Chapter 10: Image segmentation I: edge detection, thresholding, and region detection
    - Sections 10.1, 10.2, and 10.3