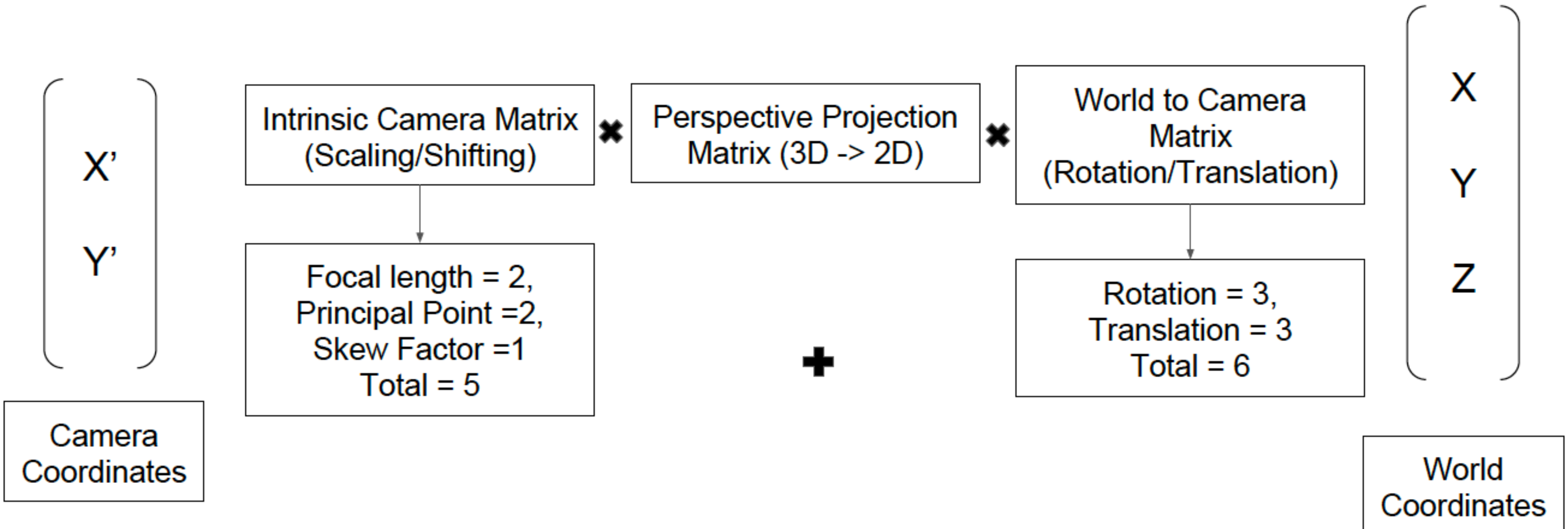
Computer Vision

Lecture 10

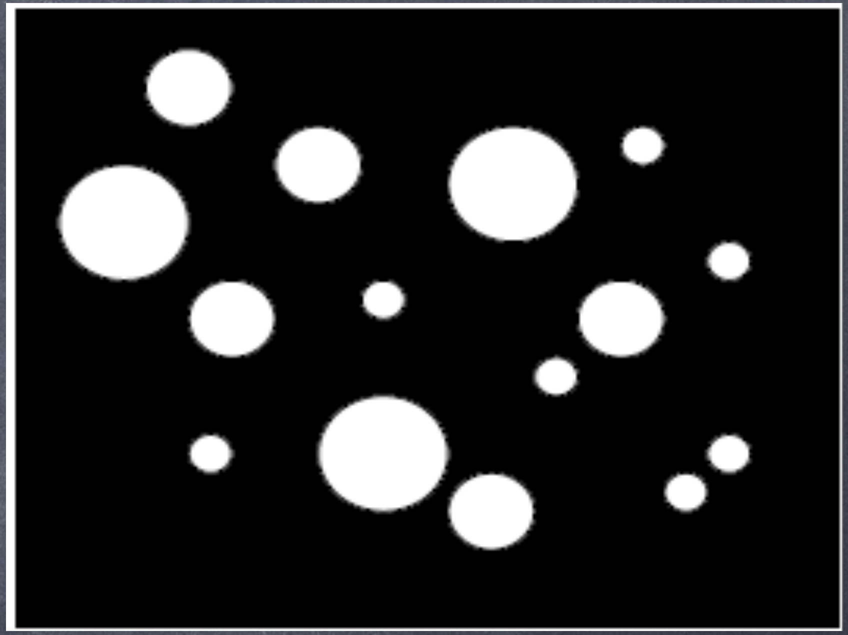
Degree of Freedom



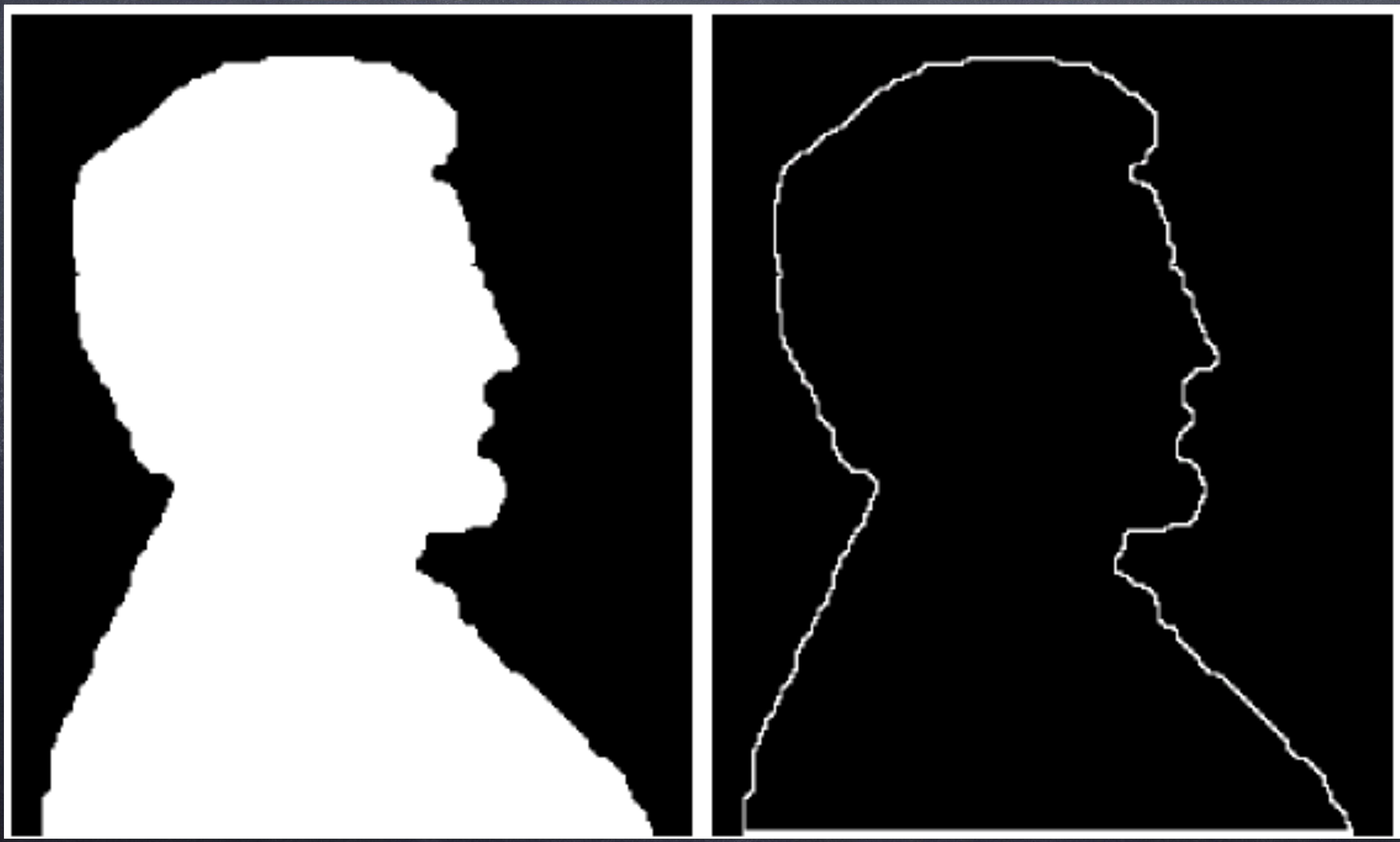
Hence, a total of 11 equations are required to estimate the parameters.

Before I move to Camera Calibration - let me take a dtour

- Find the biggest/ smallest circle
- Find the location of all circles
- Remove all circles except three big ones.



Question: boundary extraction



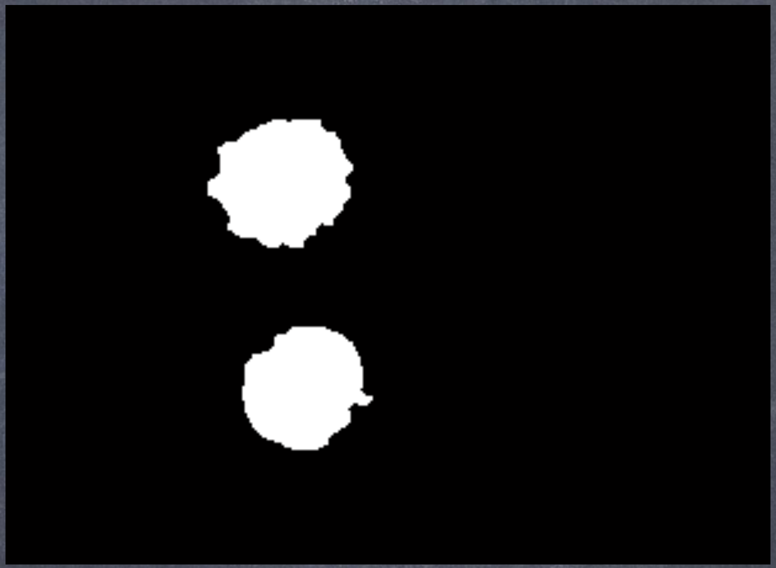
- How do we detect edges?
- How do we detect lines?
- How do we detect corners?

Preview

- Morphology About the form and structure of objects
- Mathematical morphology
  - Using set theory
  - Extract image component
  - Representation and description of region shape

Preview (cont.)

- Sets in mathematical morphology represent objects in an image



- Example
  - Binary image: the elements of a set is the coordinate (x,y) of the pixels, in Z^2
  - Gray-level image: the element of a set is the triple, (x, y, gray-value), in Z^3

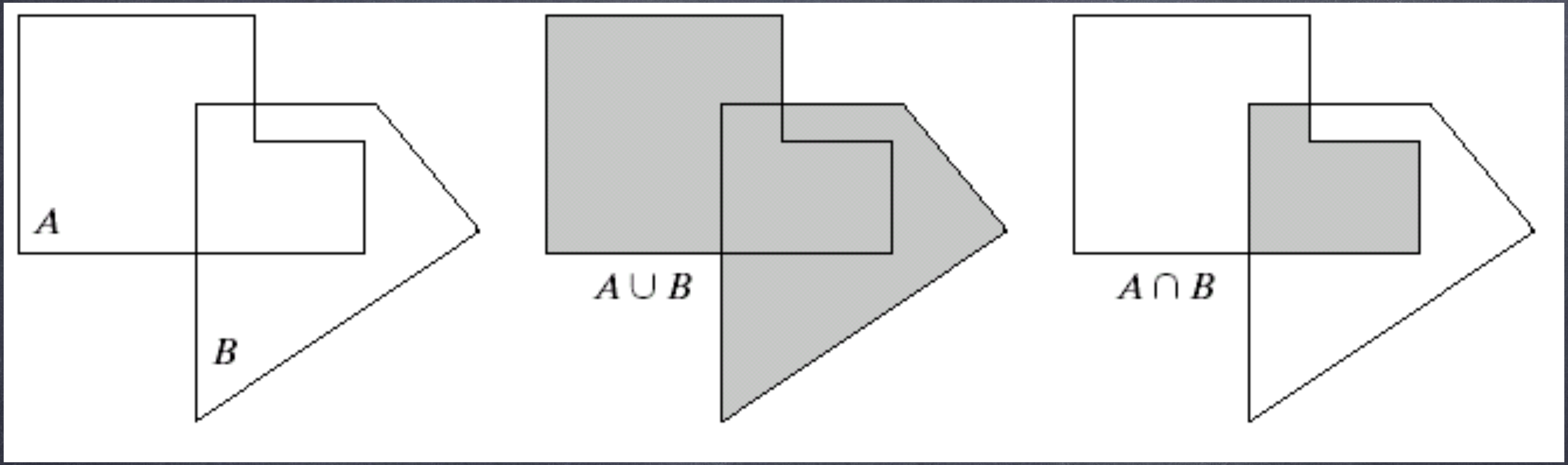
Preliminaries – set theory

- A be a set in Z^2.
- a = (a_1, a_2) is an element of A. $a \in A$
- a is **not** an element of A $a \notin A$
- Null (empty) set: $\varnothing$

Set operations

- A is a subset of B: every element of A is an element of another set B $A \subseteq B$
- Union $C = A \cup B$
- Intersection $C = A \cap B$
- Mutually exclusive $A \cap B = \varnothing$

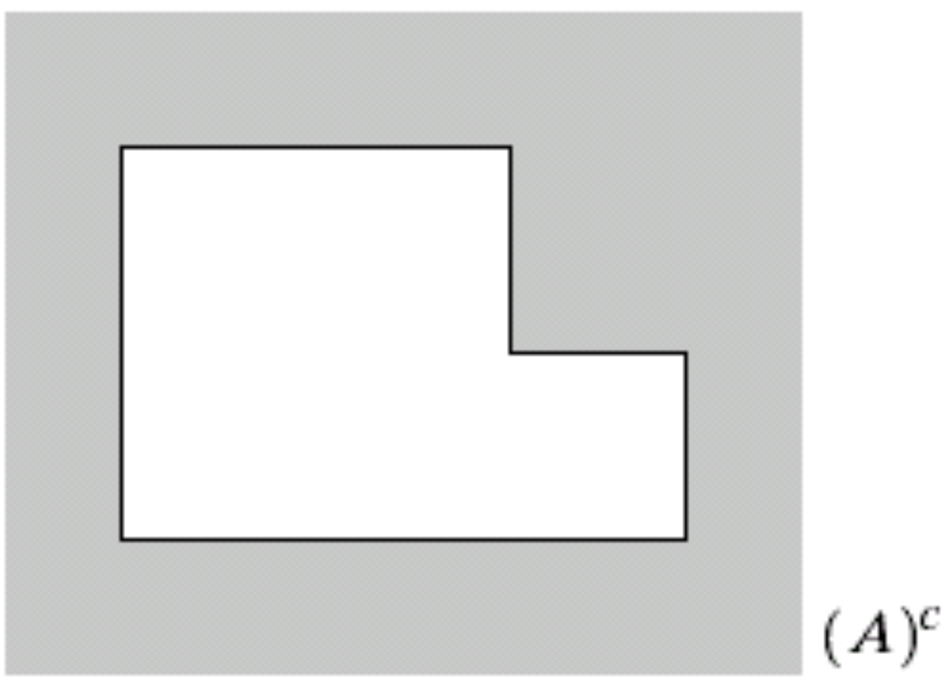
Graphical examples

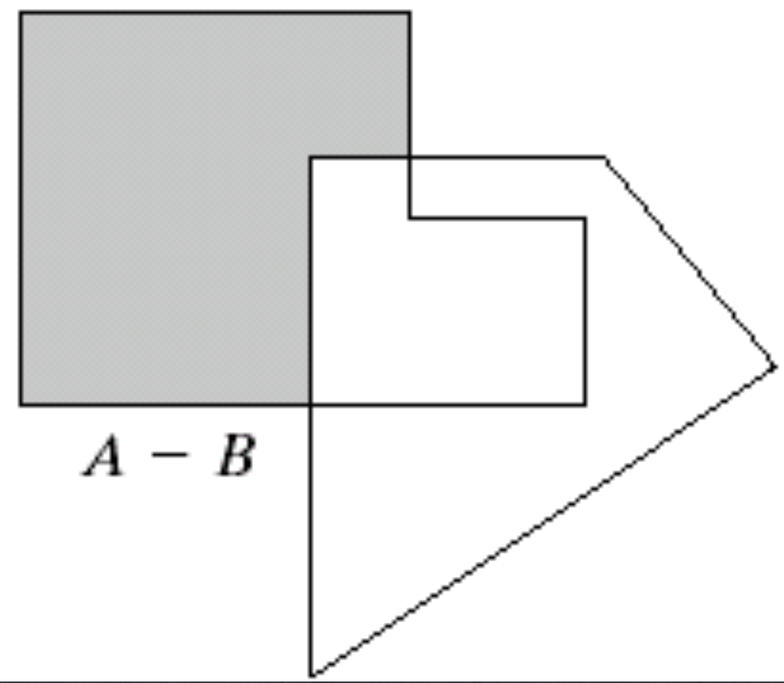


Graphical examples (cont.)

$$A^c = \left\{ w \middle| w \notin A \right\}$$

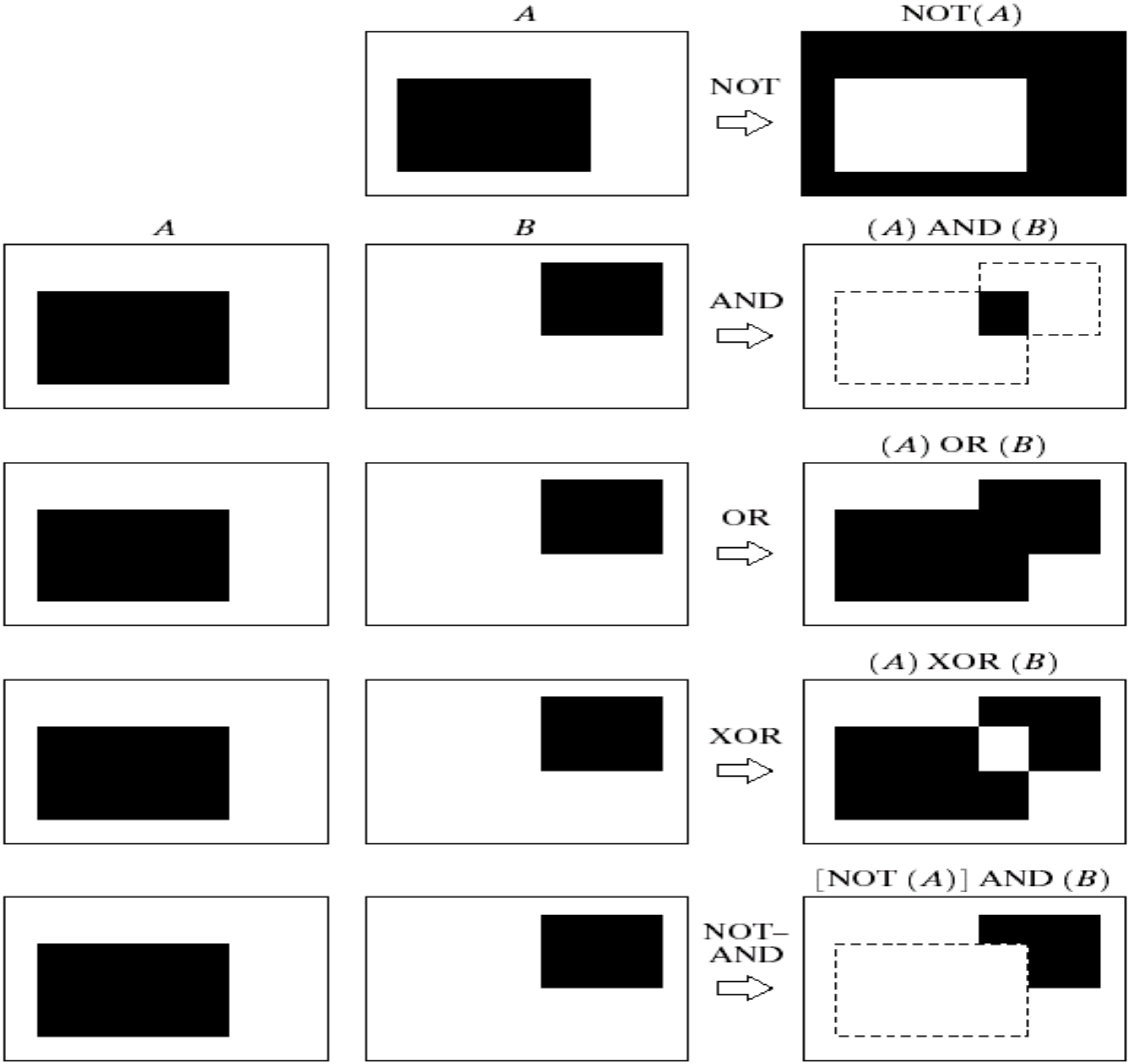
$$A - B = \left\{ w \middle| w \in A, w \notin B \right\}$$





Logic operations on binary images

p	q	p AND q (also $p \cdot q$)	p OR q (also $p + q$)	NOT (p) (also $\bar{p}$)
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0



$A \cap B$

$A \cup B$

$B - A$

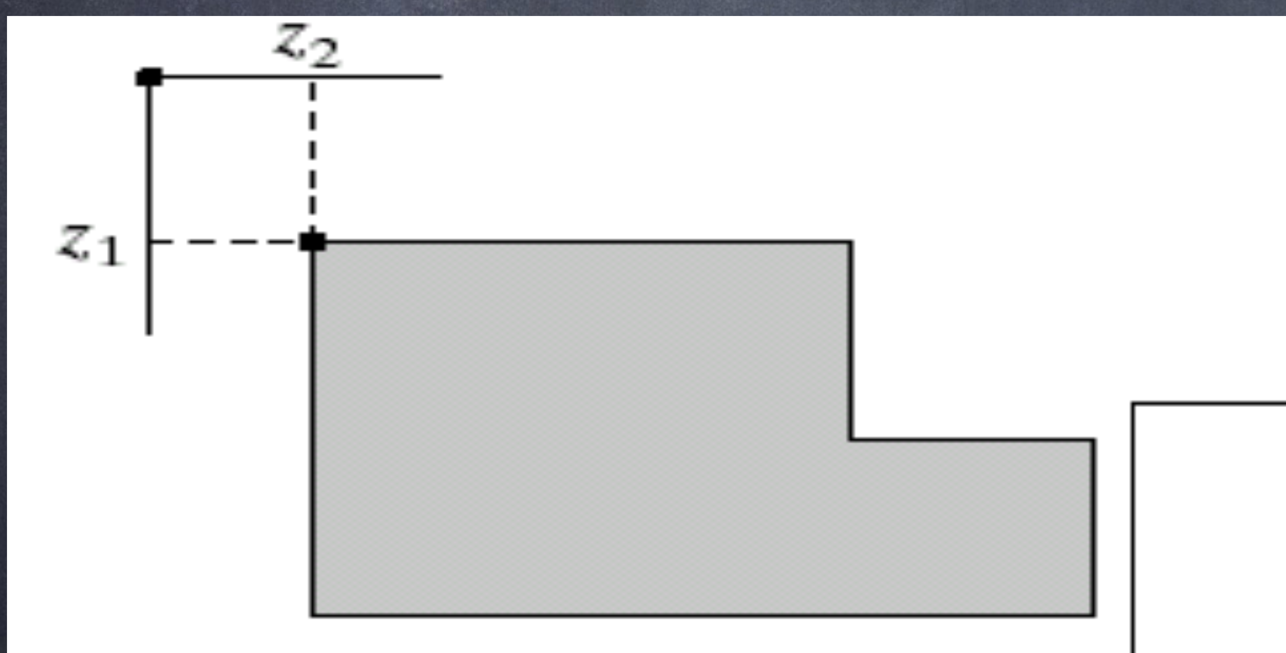
Special set operations for morphology

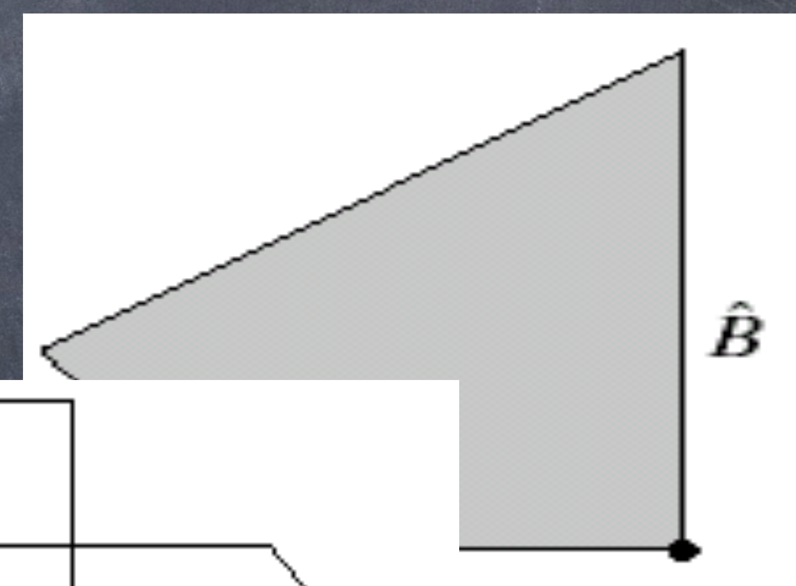
translation

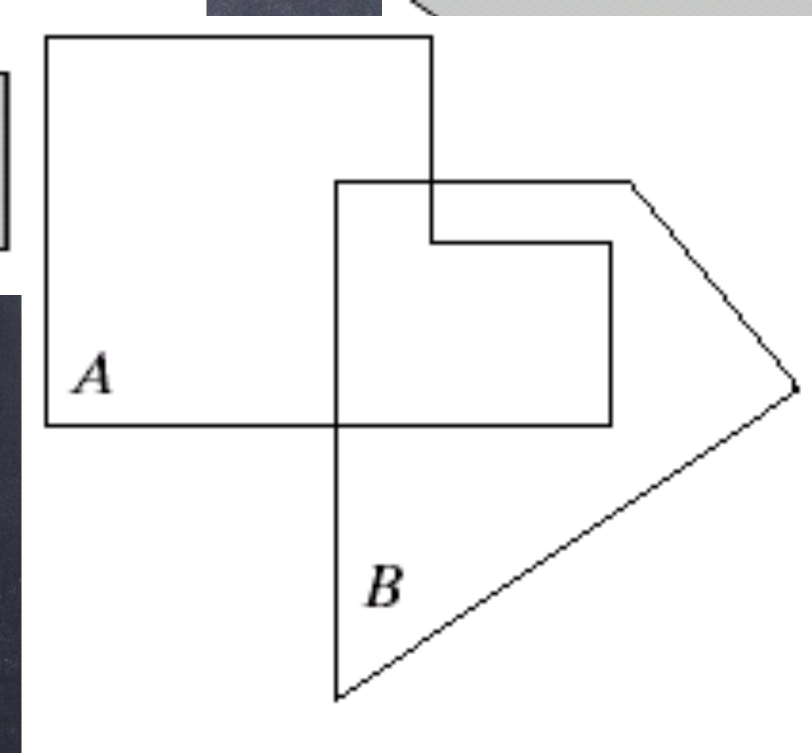
$$(A)_z = \{c \mid c = a + z, \text{ for } a \in A\}$$

reflection

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

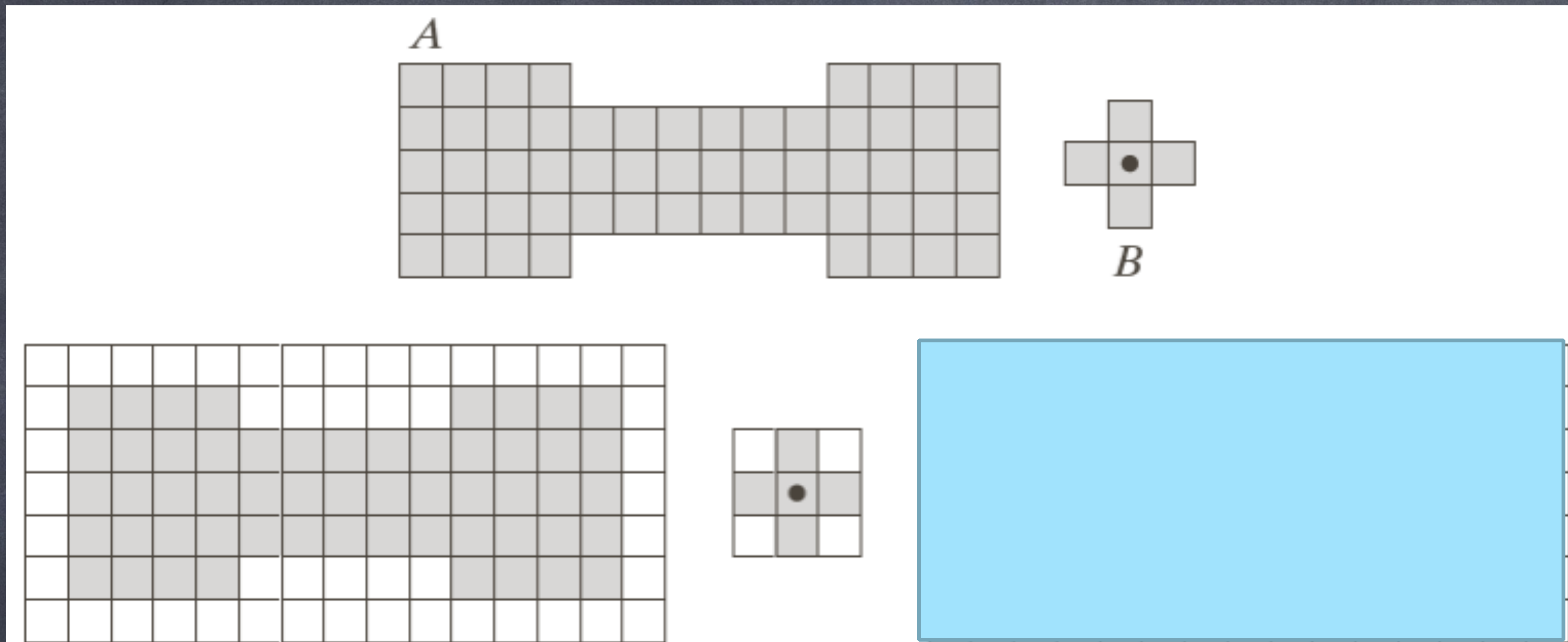






Structuring element (SE)

- small set to probe the image under study
- for each SE, define origin
- shape and size must be adapted to geometric properties for the objects

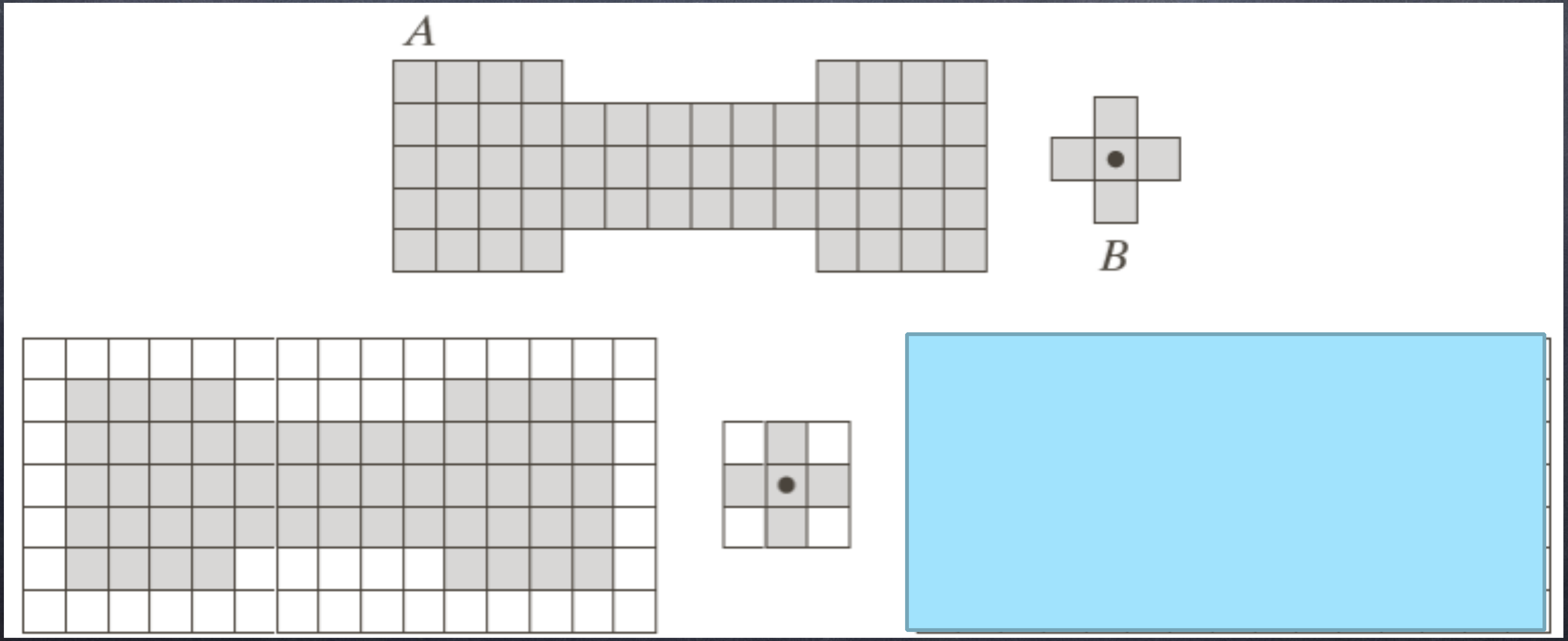


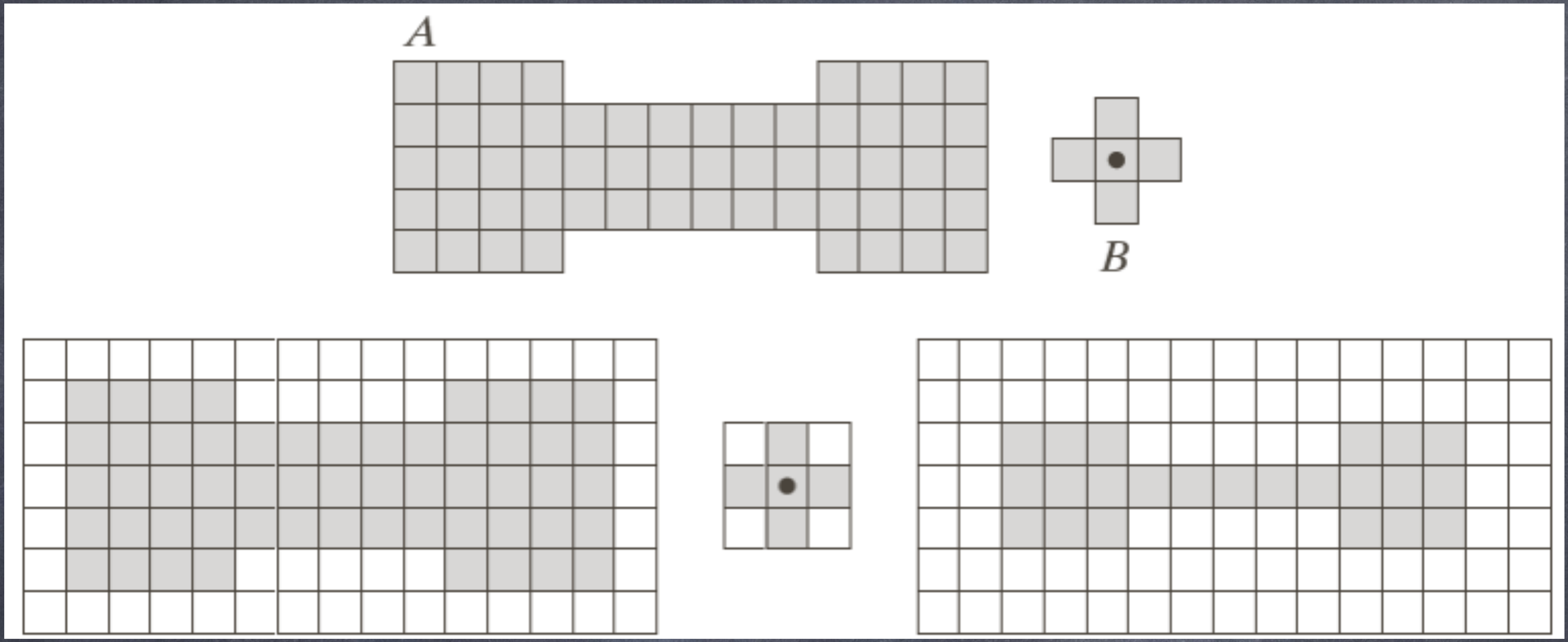
a b
c d e

FIGURE 9.3 (a) A set (each shaded square is a member of the set). (b) A structuring element. (c) The set padded with background elements to form a rectangular array and provide a background border. (d) Structuring element as a rectangular array. (e) Set processed by the structuring element.

Operation

- Create a new set by running B over A so that the origin of B visits every element of A.
- At each location of the origin of B, if B is completely contained in A, mark that location as member of the new set otherwise not.





a b
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FIGURE 9.3 (a) A set (each shaded square is a member of the set). (b) A structuring element. (c) The set padded with background elements to form a rectangular array and provide a background border. (d) Structuring element as a rectangular array. (e) Set processed by the structuring element.

Dilation

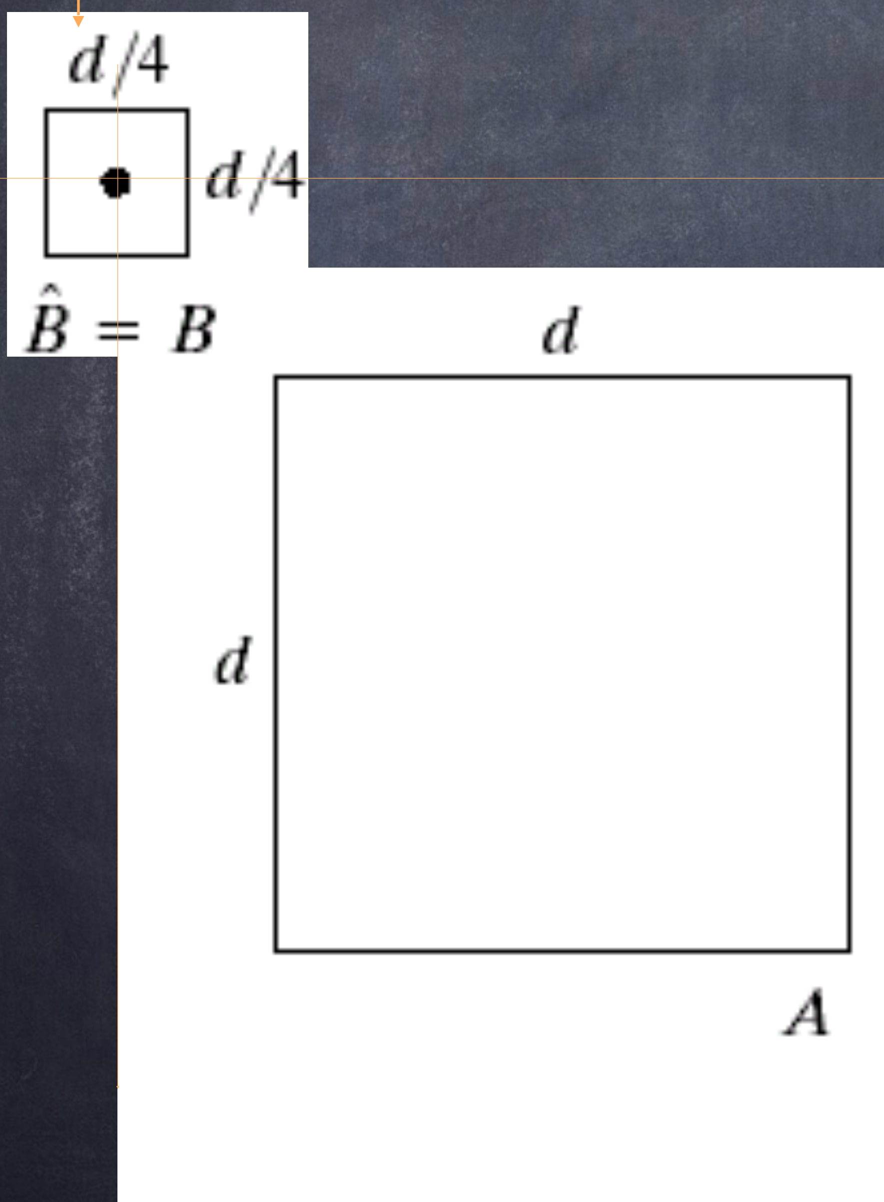
- Dilation of A by B is the set of all displacements, z, such that $\hat{B}$ and A overlap by at least one element

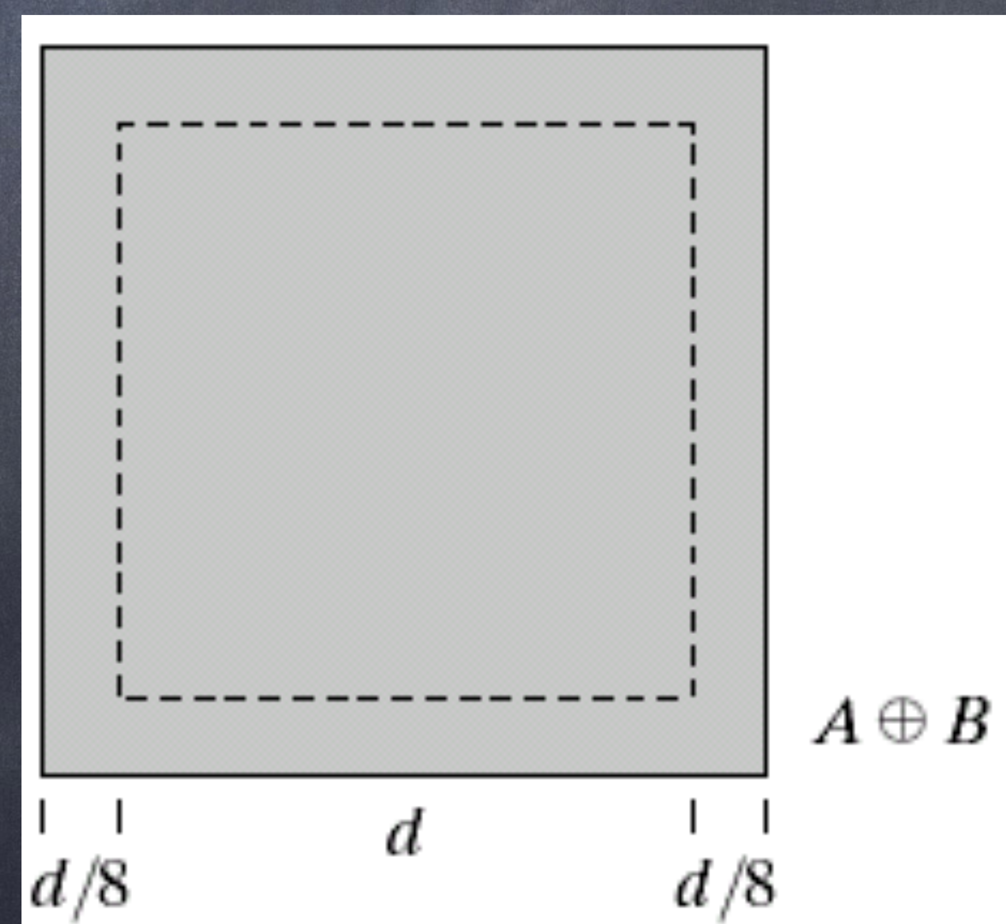
$$A \oplus B = \left\{ z \,\middle|\, (\hat{B})_z \cap A \neq \varnothing \right\}$$

Dilation

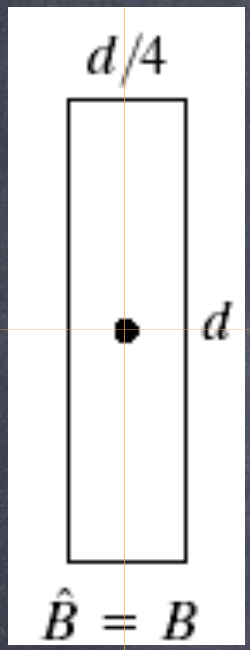
$$A \oplus B = \left\{ z \,\middle|\, (\hat{B})_z \cap A \neq \varnothing \right\}$$

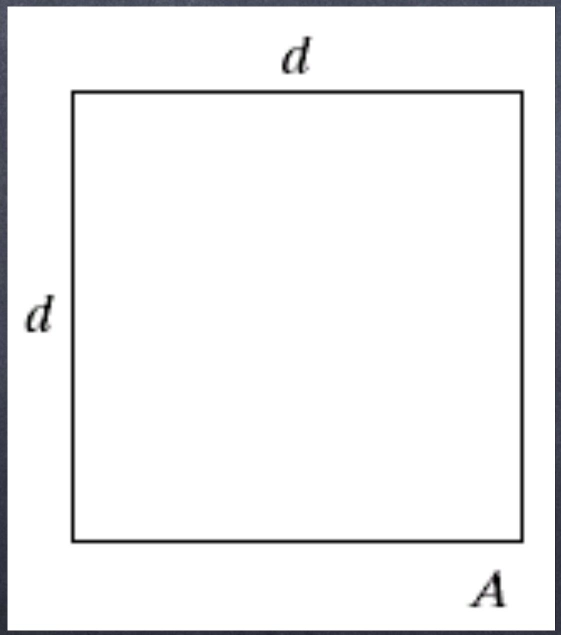
B:structuring element

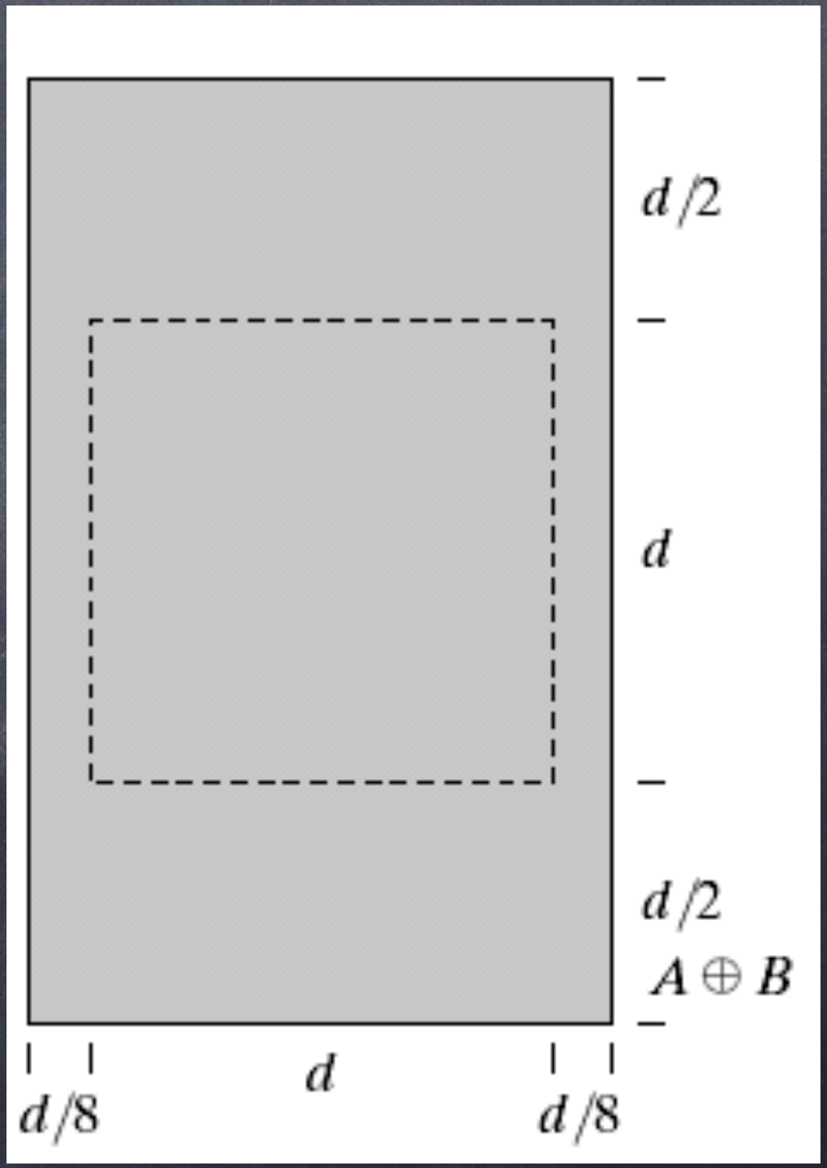




Dilation





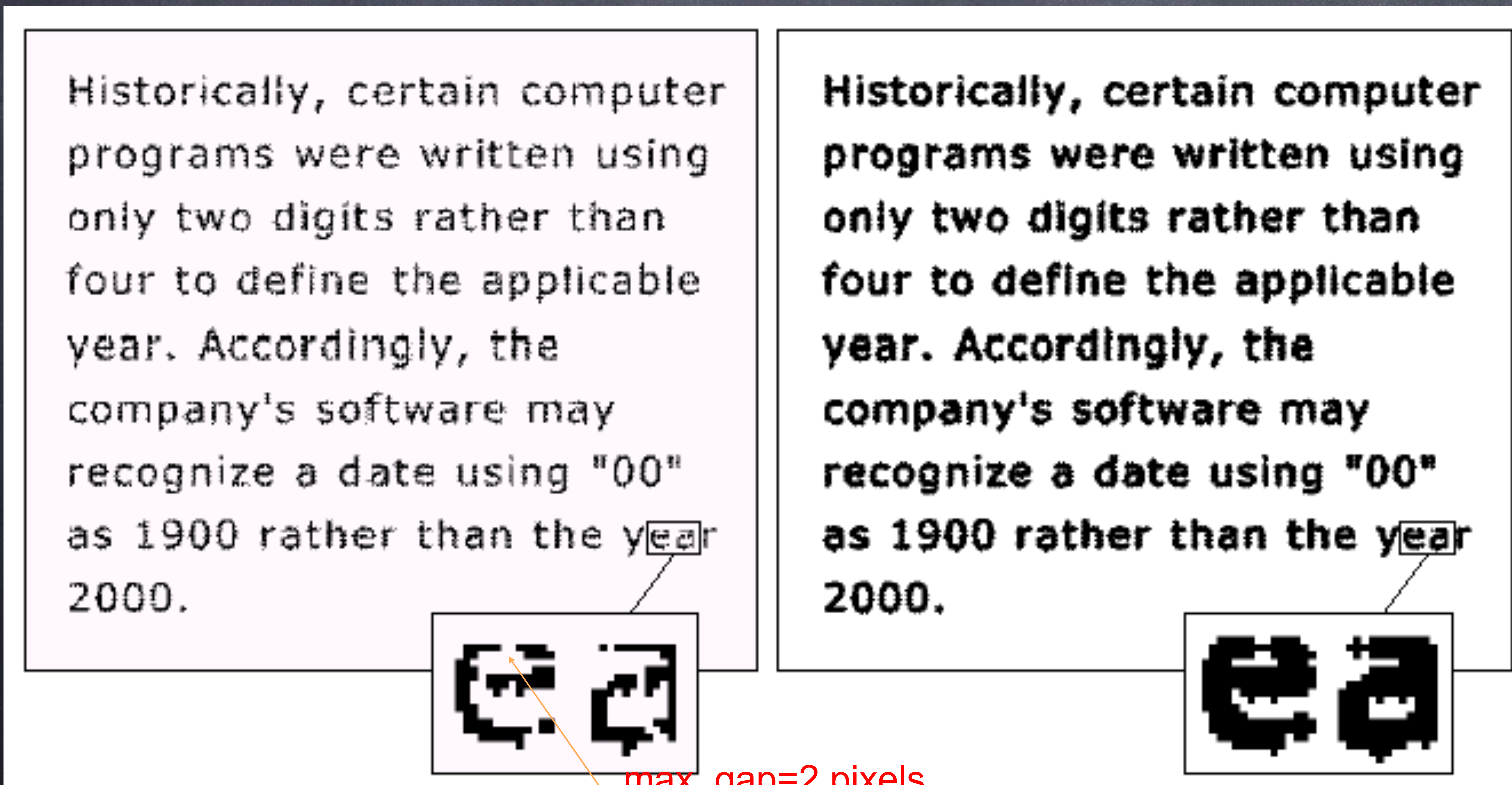


Application of dilatio… bridging gaps in imag…

0	1	0
1	1	1
0	1	0

Structuring element

Effects: increase size, fill gap


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.

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Erosion

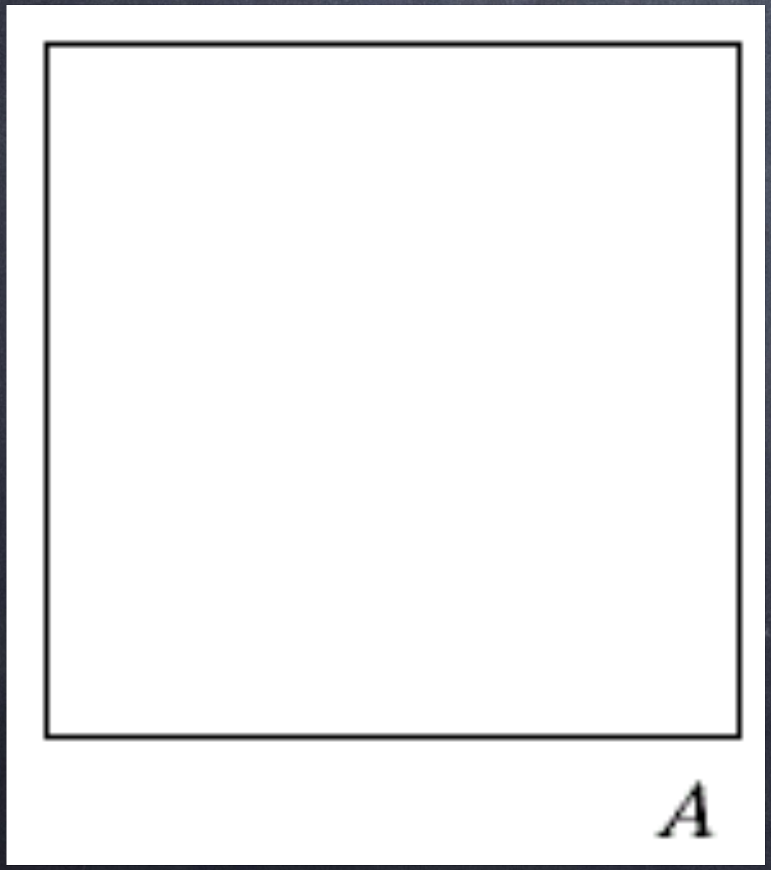
- Erosion of A by B is the set of all points z such that B, translated by z, is contained in A.

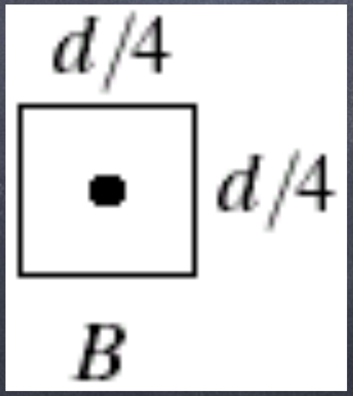
$$A \ominus B = \left\{ z \,\middle|\, (B)_z \subseteq A \right\}$$

Erosion

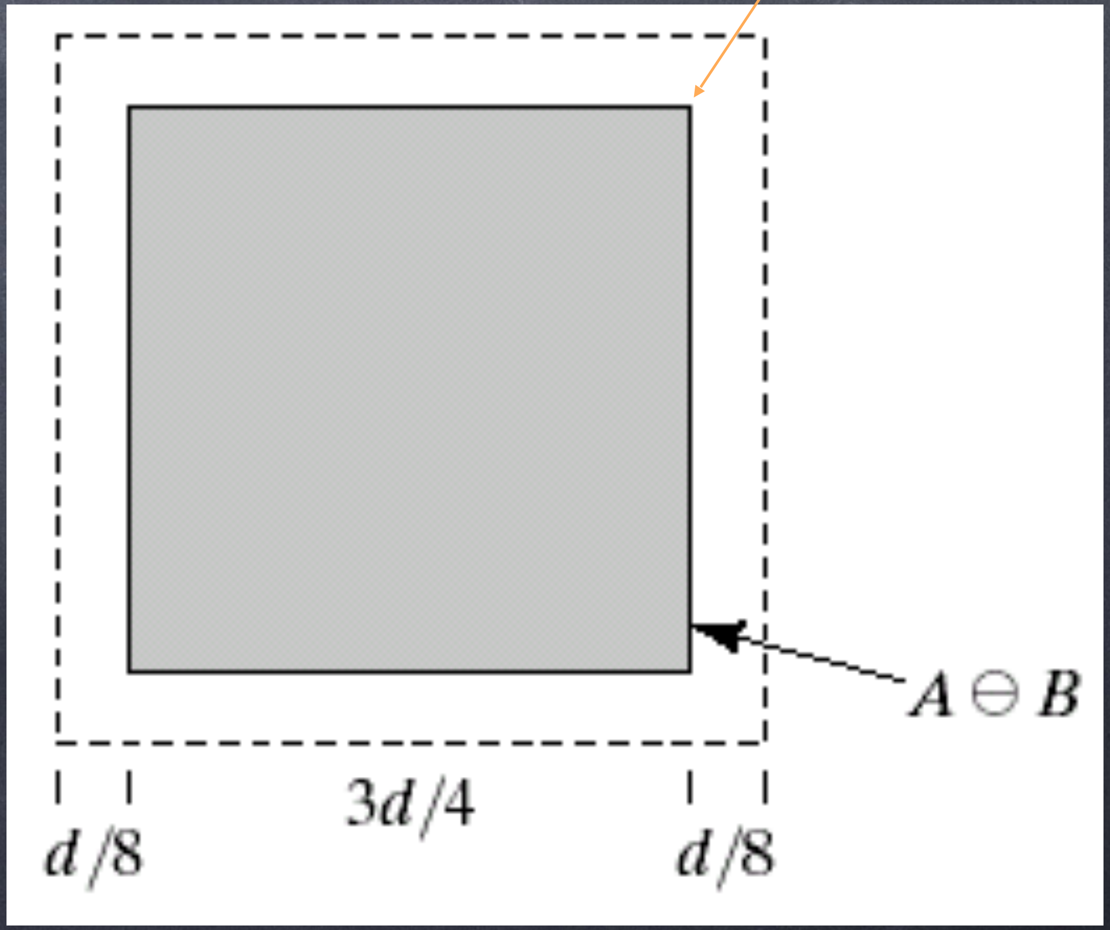
$$A \ominus B = \left\{ z \,\middle|\, (B)_z \subseteq A \right\}$$

z: displacement

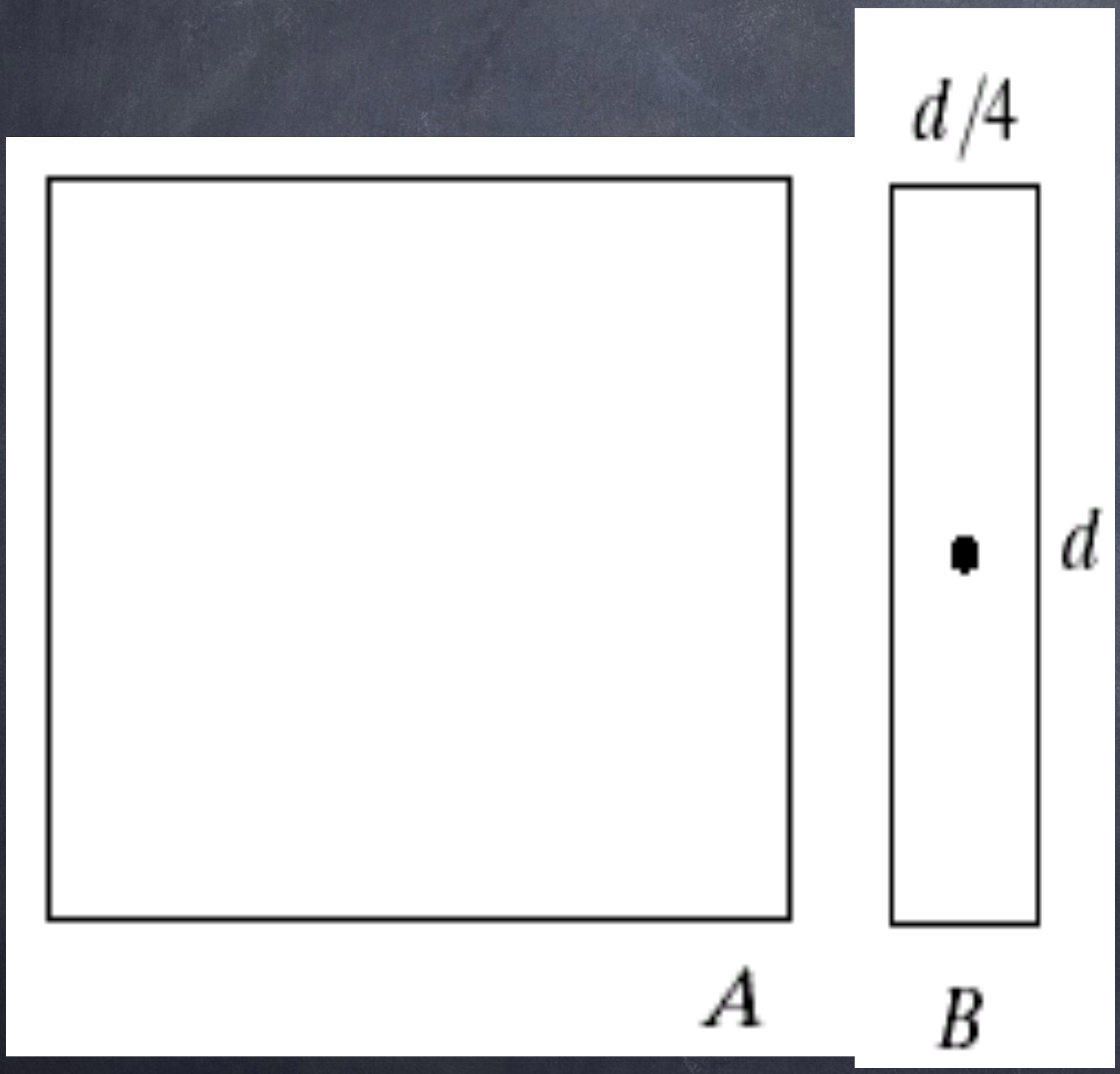


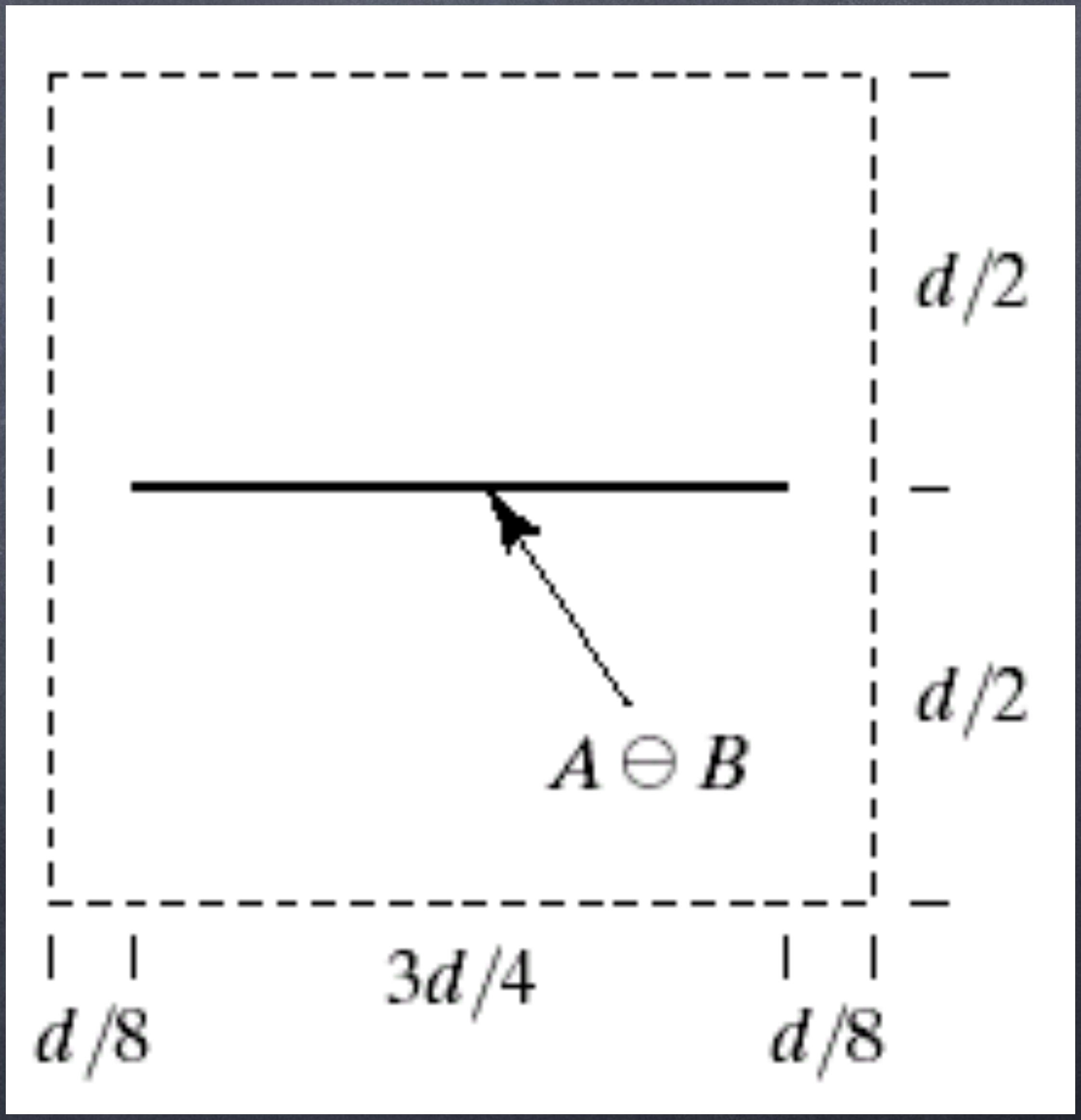


B:structuring element



Erosion (cont.)

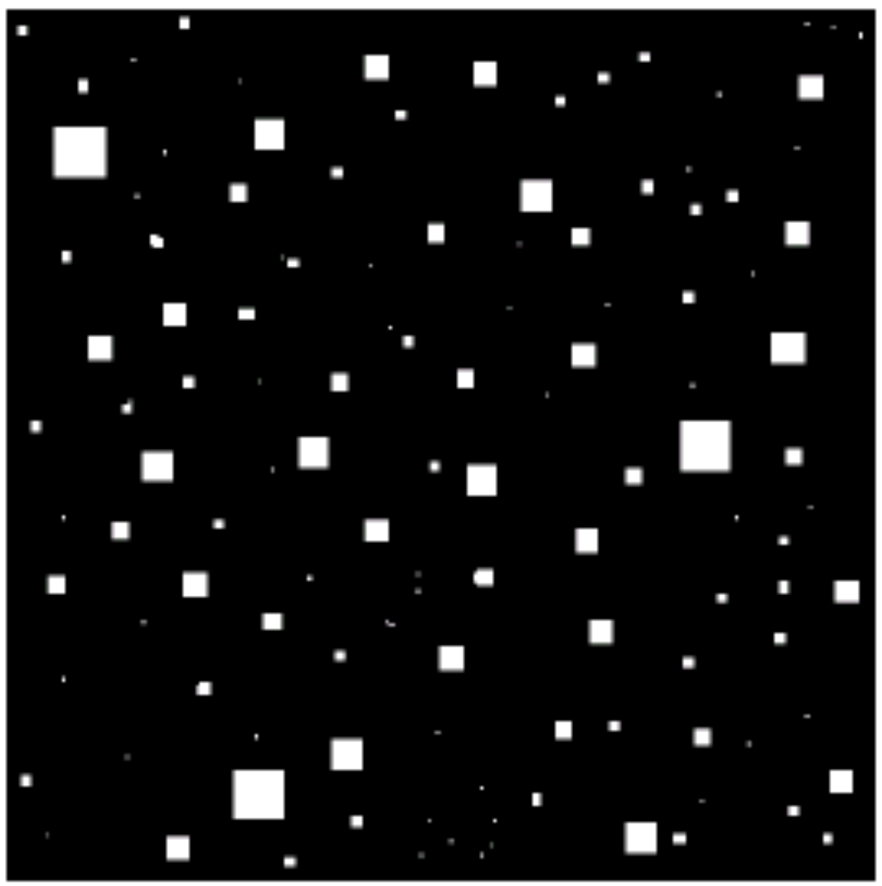




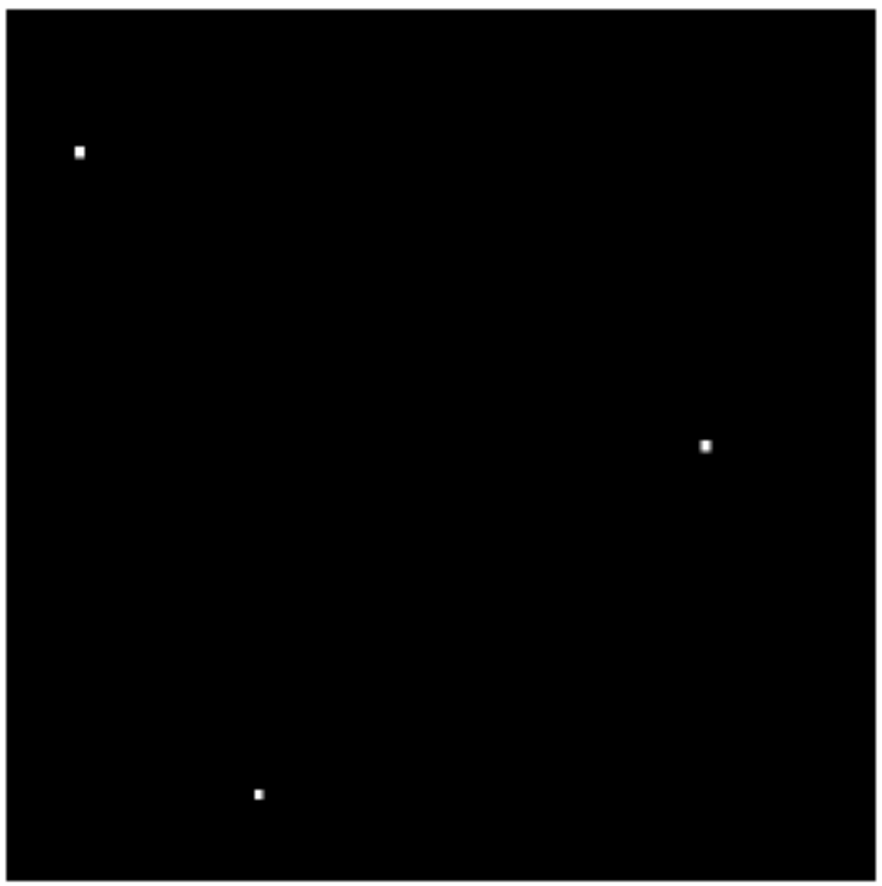
Application of erosion: eliminate irrelevant detail

Squares of size
1,3,5,7,9,15 pixels

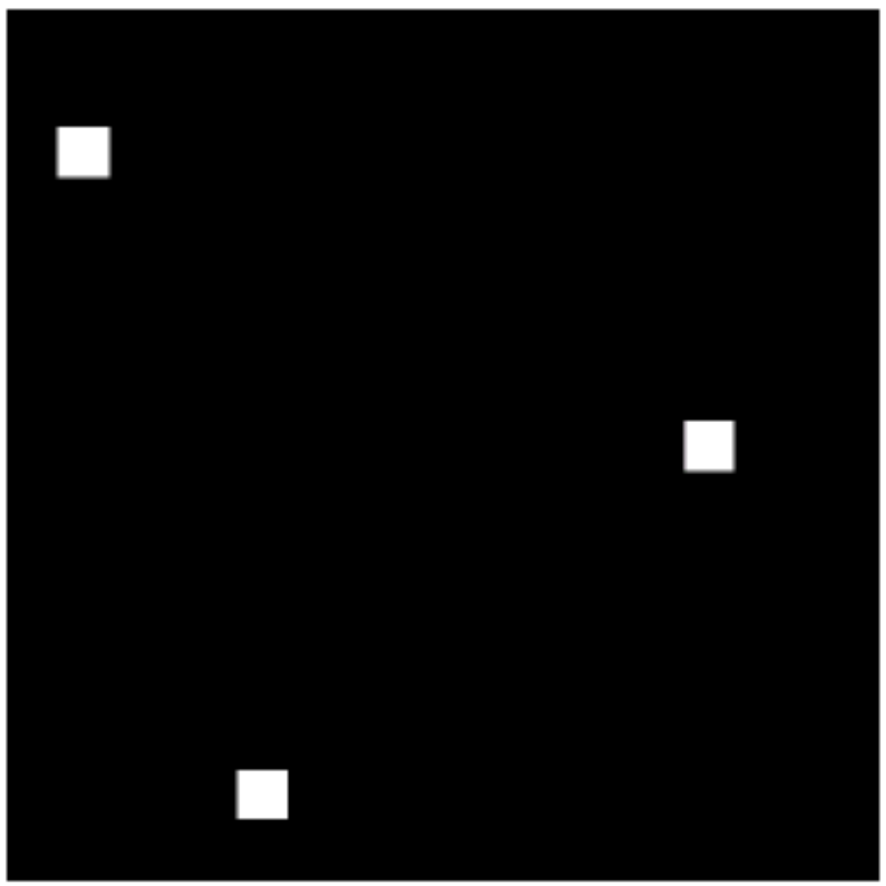
Erode with
13x13 square



original image



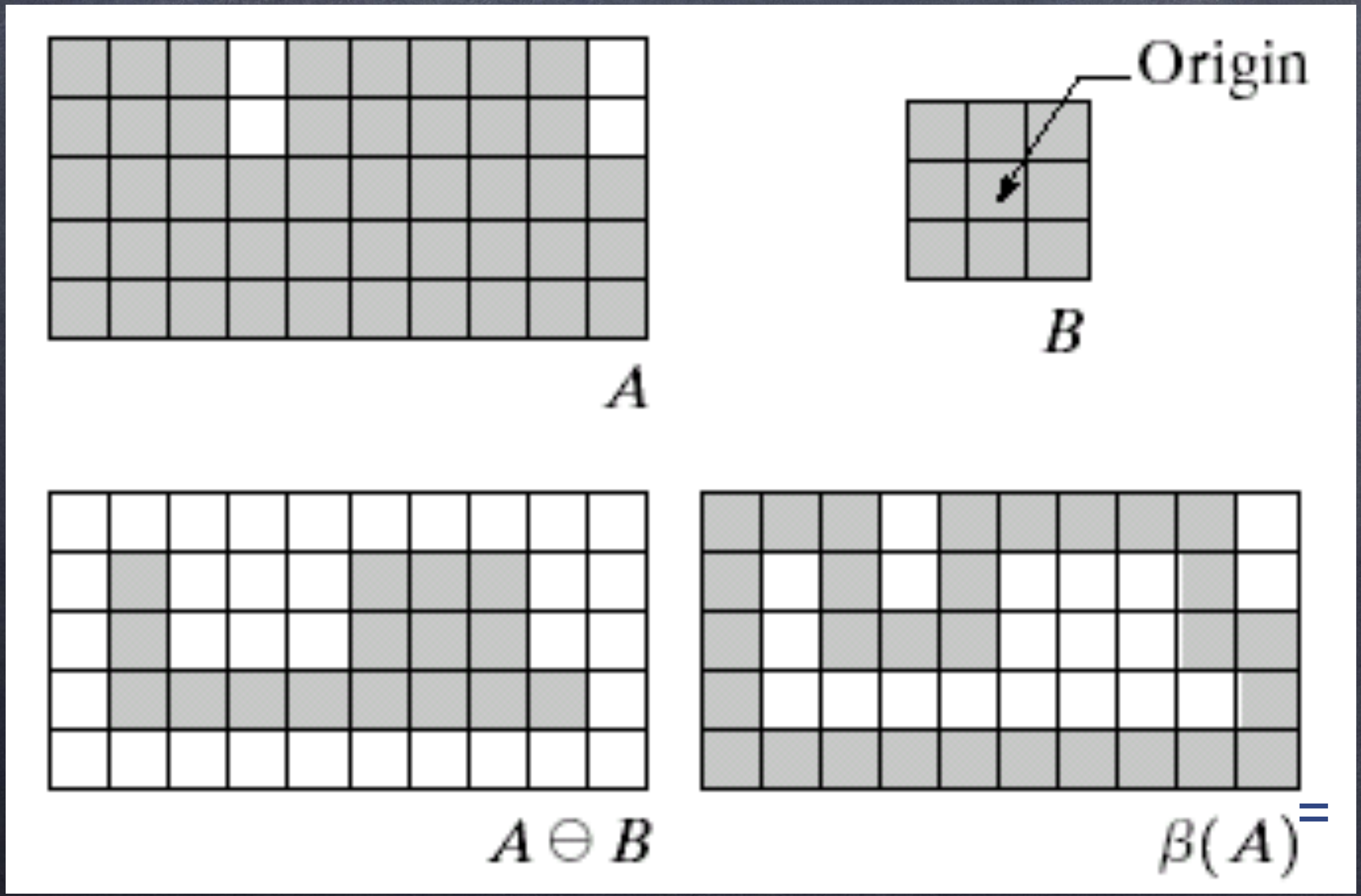
erosion



dilation

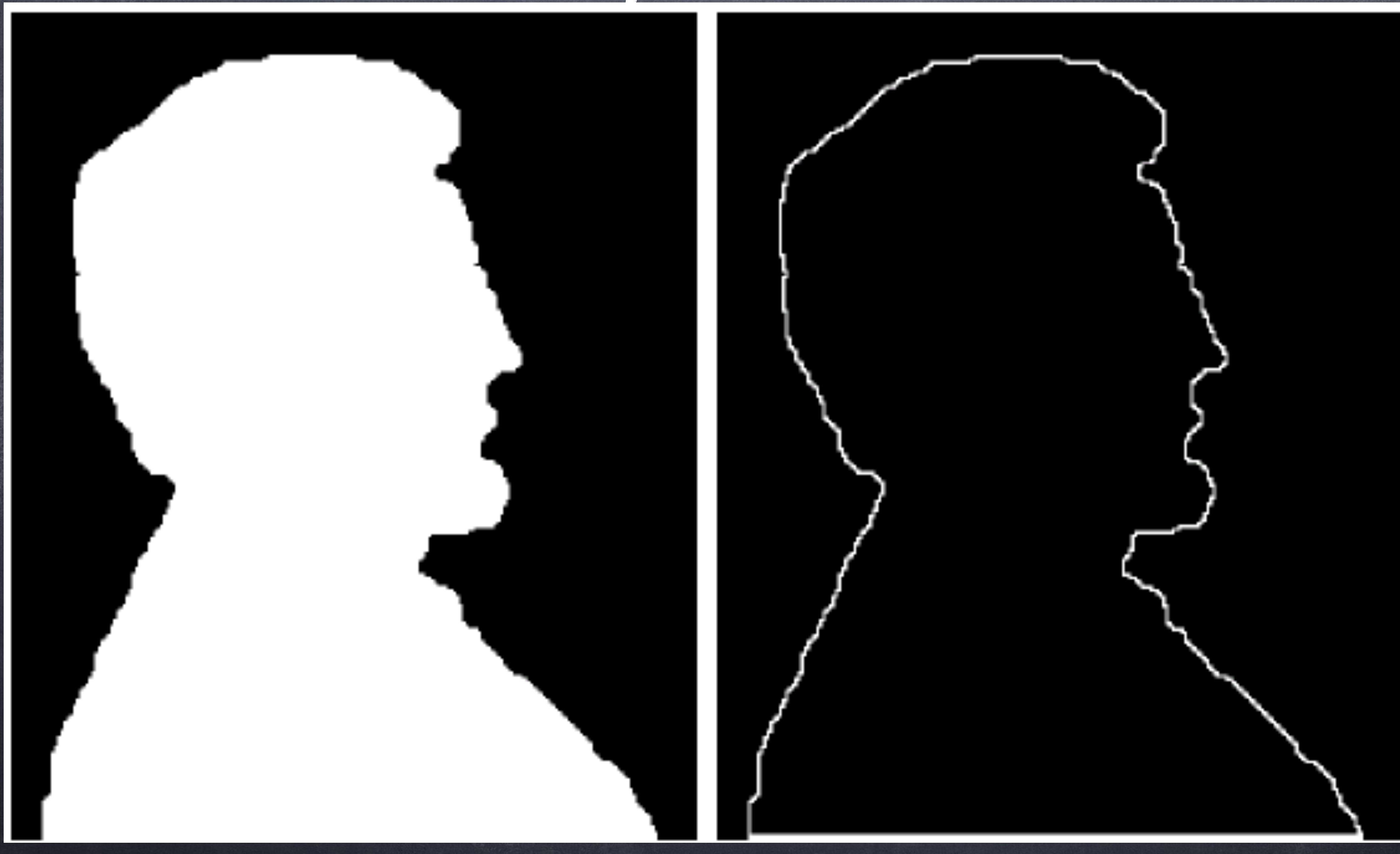
Application: Boundary extraction

- Extract boundary of a set A:
  - First erode A (make A smaller)
  - A – erode(A)

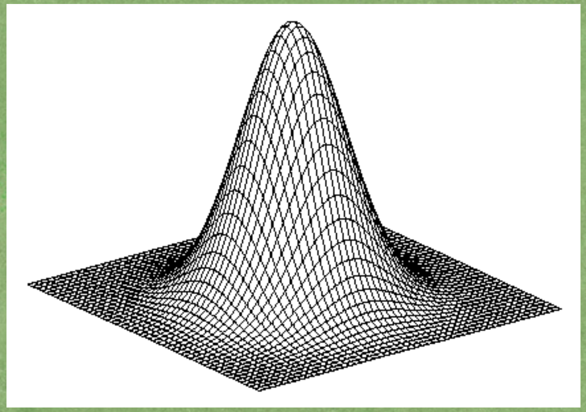


$$A - (A \ominus B)$$

Application: boundary extraction

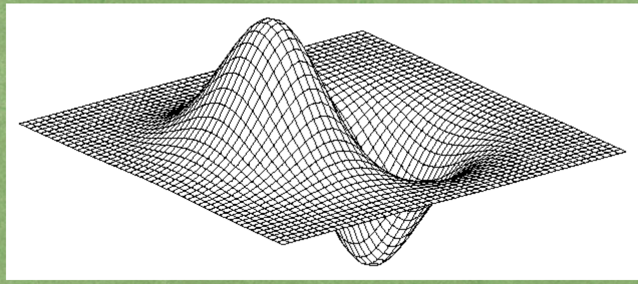


Edge Detection



Gaussian

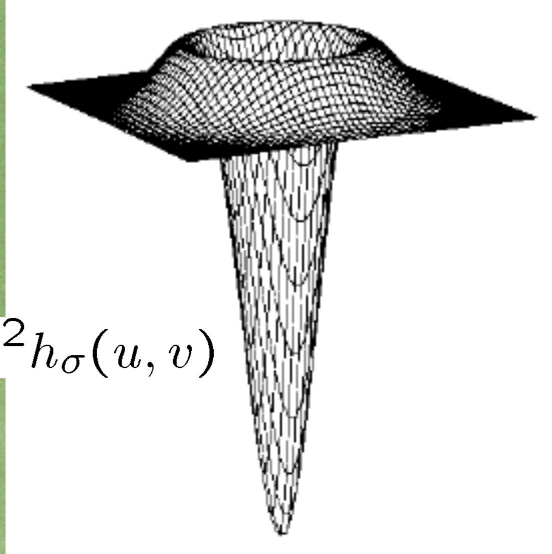
$$h_\sigma(u,v) = \frac{1}{2\pi\sigma^2} e^{-\frac{u^2+v^2}{2\sigma^2}}$$



derivative of Gaussian

$$\frac{\partial}{\partial x} h_\sigma(u,v)$$

Laplacian of Gaussian



$$\nabla^2 h_\sigma(u,v)$$

∇^2 is the **Laplacian** operator:

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

Canny edge detector

Filter image with derivative of Gaussian

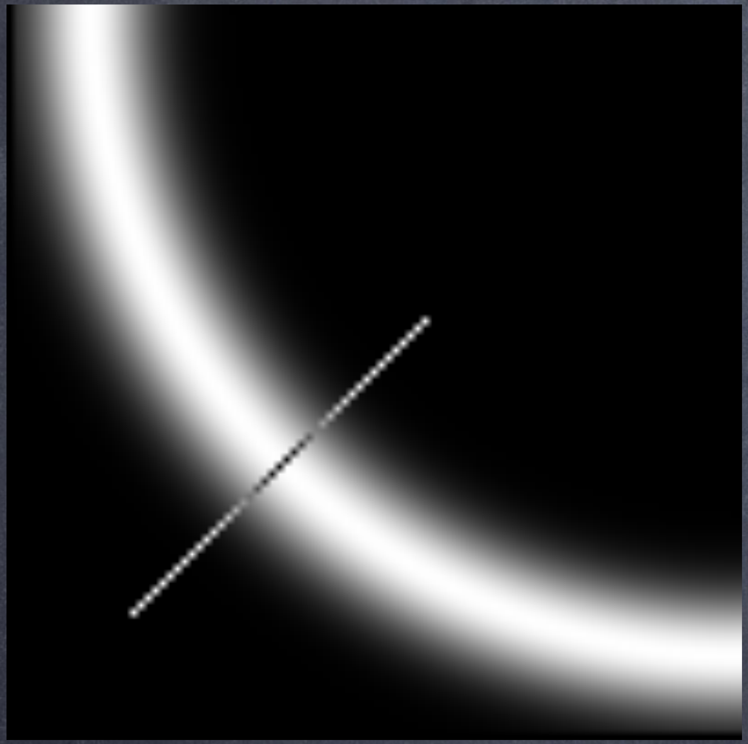
Find magnitude and orientation of gradient

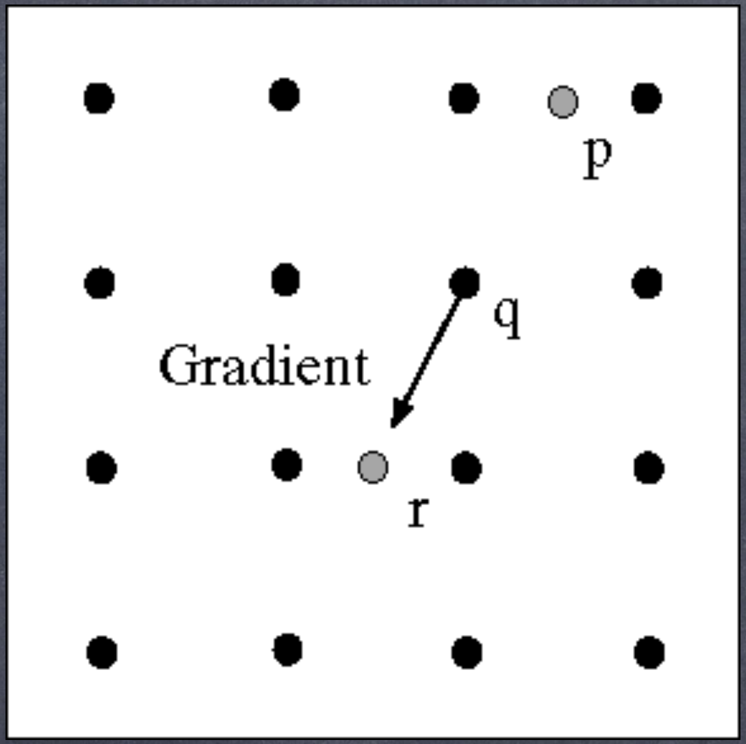
Non-maximum suppression

Linking and thresholding

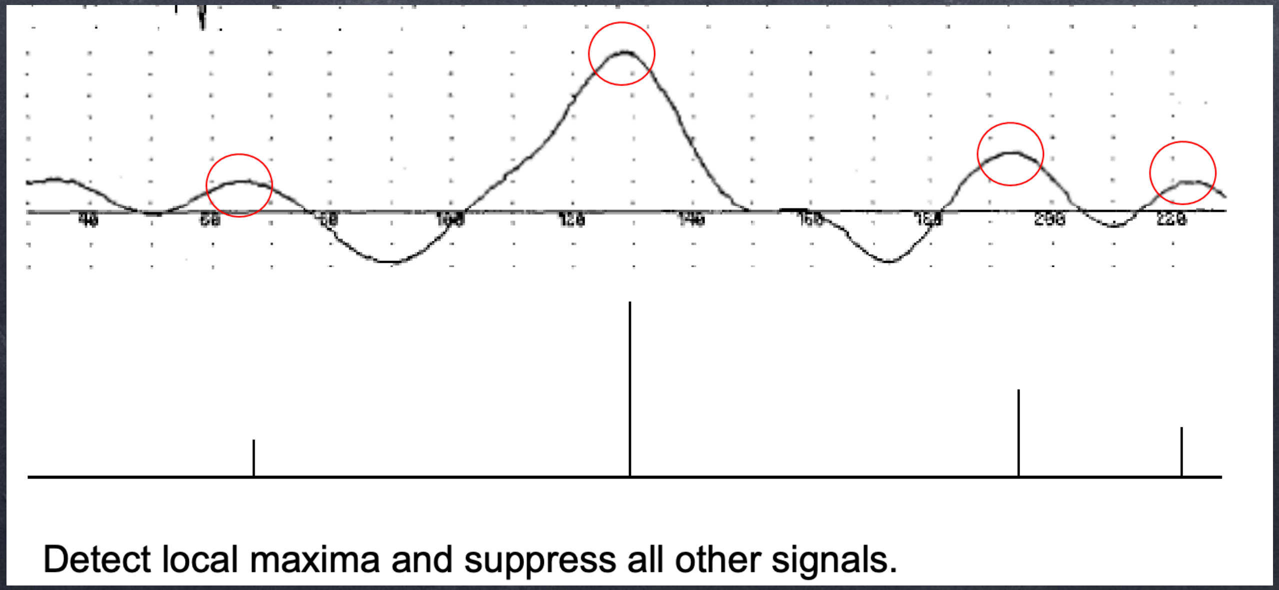
Source: D. Lowe, L. Fei-Fei

Non-maximum suppression





Check if pixel is local maximum along gradient direction



Line Detection

- Define the response of the mask:

$$R = \sum_{i=1}^{9} w_i z_i$$

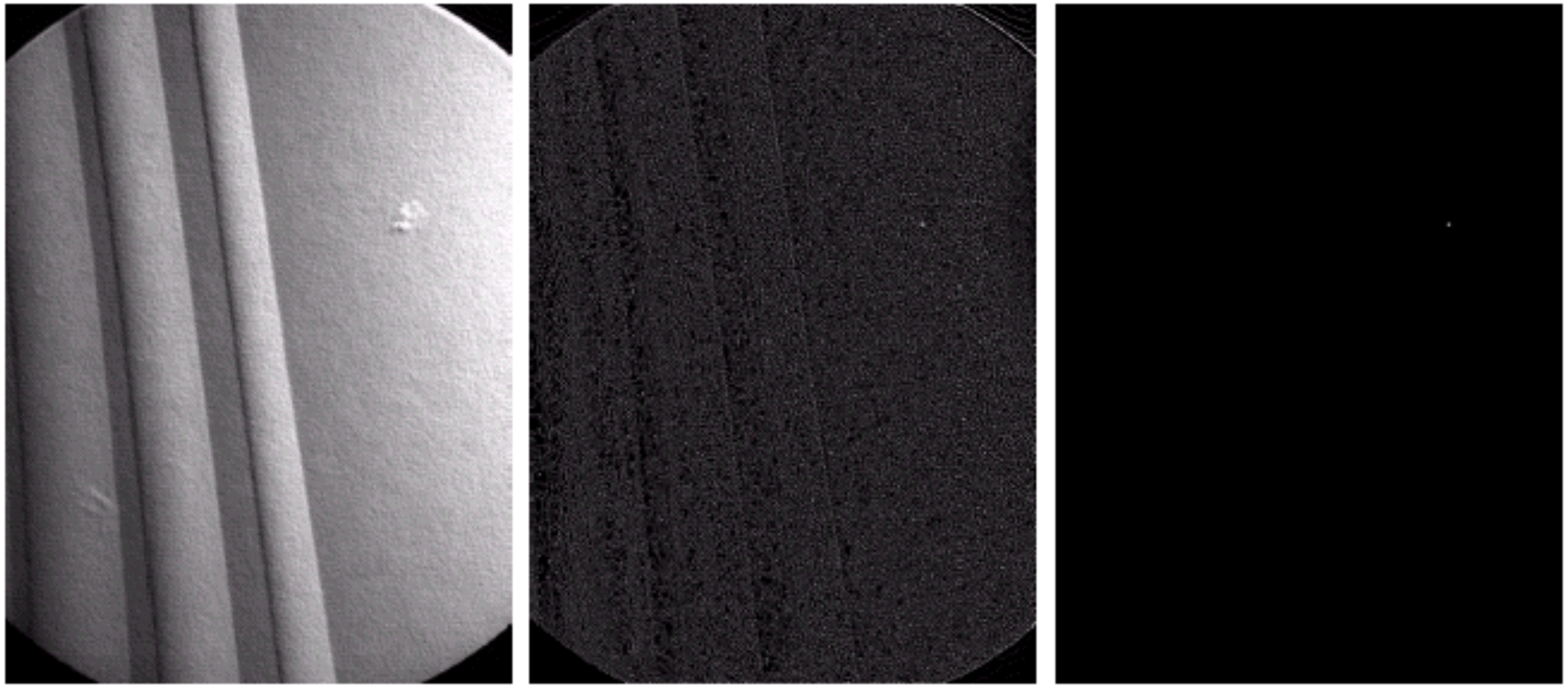
- Point detection: $|R| \geq T$

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Detection of Discontinuities

Point Detection Example

−1	−1	−1
−1	8	−1
−1	−1	−1



a
b c d

FIGURE 10.2
(a) Point detection mask.
(b) X-ray image of a turbine blade with a porosity.
(c) Result of point detection.
(d) Result of using Eq. (10.1-2).
(Original image courtesy of X-TEK Systems Ltd.)

Line Detection

- Masks that extract lines of different directions.

FIGURE 10.3 Line masks.

−1	−1	−1
2	2	2
−1	−1	−1

Horizontal

−1	−1	2
−1	2	−1
2	−1	−1

+45°

−1	2	−1
−1	2	−1
−1	2	−1

Vertical

2	−1	−1
−1	2	−1
−1	−1	2

−45°

Corner Detection

- Next lecture
- Need to discuss
  - Exam 1
  - Mid-term course feedback