Morphological image processing, Polarization microscopy

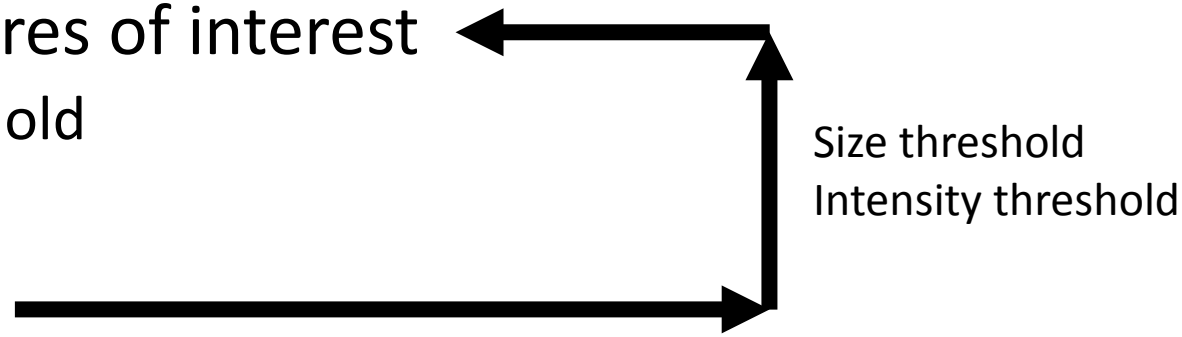
- Last class
  - Contrast
  - Phase contrast imaging
  - Dark field microscopy
- This class
  - Morphological image processing
  - Morphological operators

Image processing workflow

- Load images
- Pre-process images
- Segment features of interest
- Extract data
- Process data

Image processing workflow

- Load images
  - imread
- Pre-process images
- Segment features of interest
  - Global threshold
- Extract data
  - reigonprops
- Process data
  - Fit curves



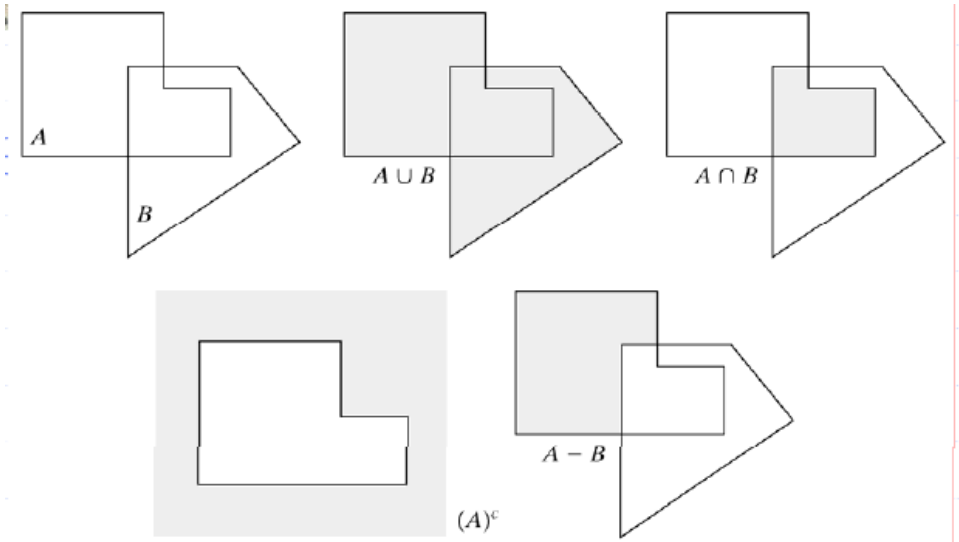
Size threshold
Intensity threshold

Preprocessing Images

- Correct for imperfections in your imaging
  - Uneven illumination
  - High background
  - Noise
  - Etc…
- Should be a back and forth between pre-processing and data collection
- Many things are easier to correct on the data collection side

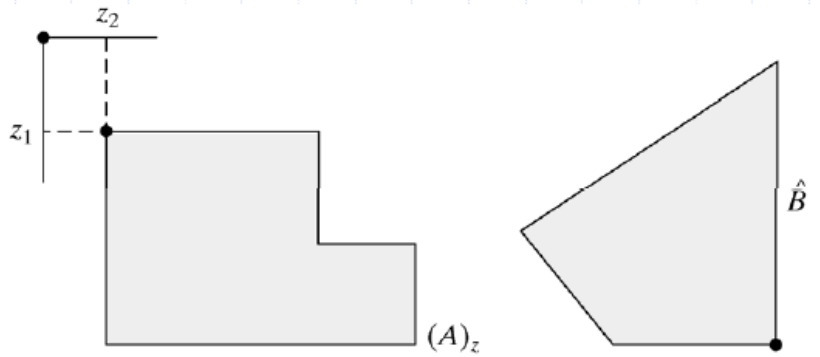
Morphological processing

- Extracting details of images by exploiting shapes
- Very useful in pre-image processing of cells
- Helpful to clean up and segment images before proper analysis
- Based on intersections of shapes



d e

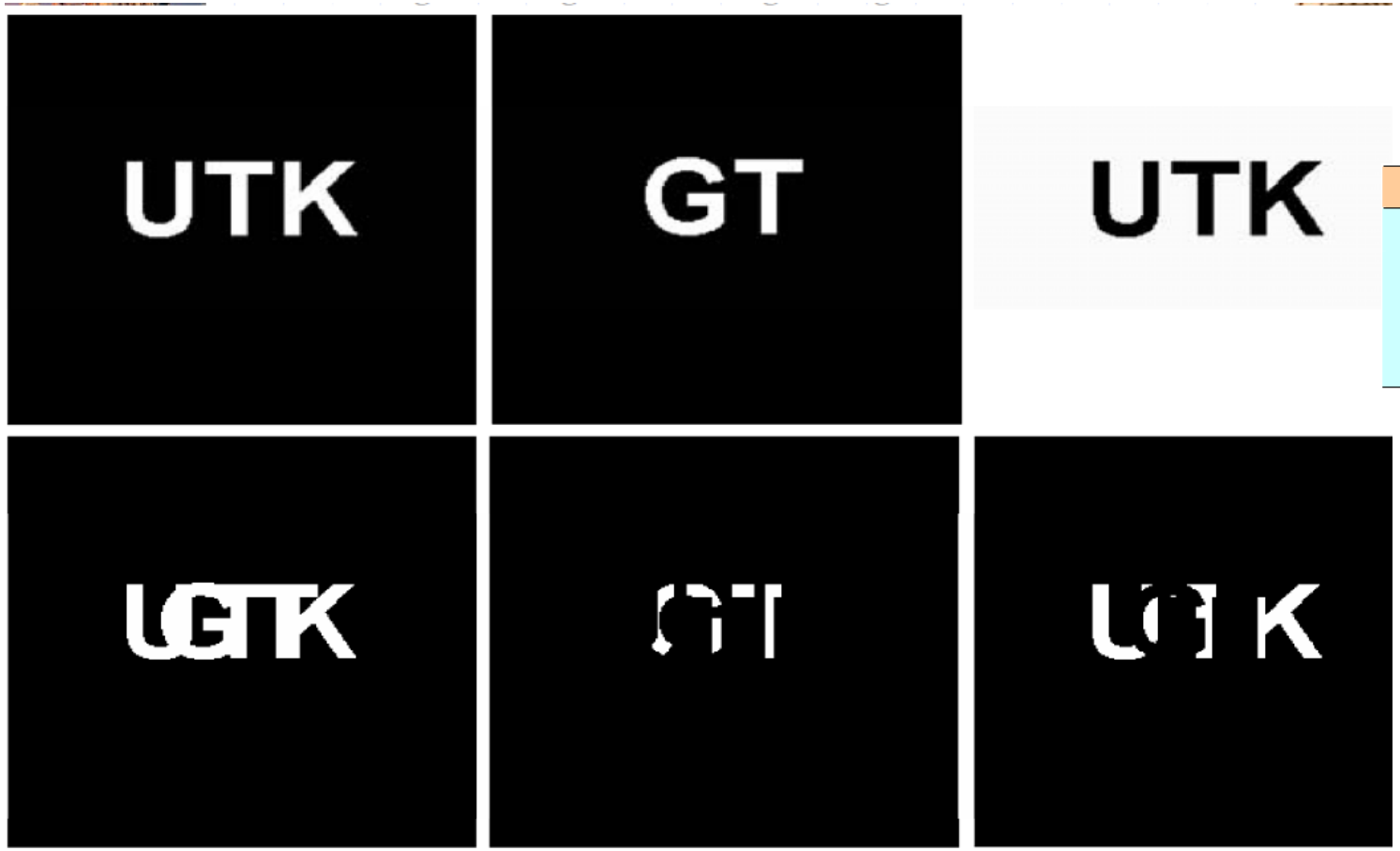
FIGURE 9.1
(a) Two sets A and B. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B.



a b

FIGURE 9.2
(a) Translation of A by z.
(b) Reflection of B. The sets A and B are from Fig. 9.1.

Examples of intersecting sets



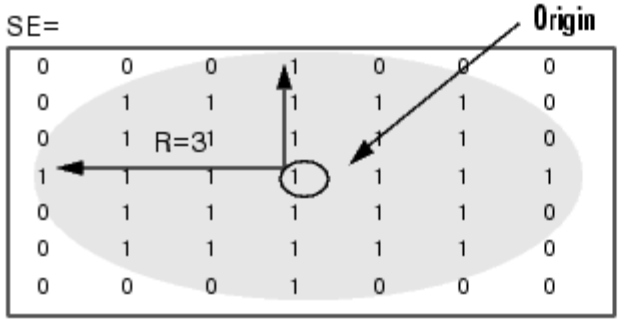
a b c
d e f

FIGURE 9.3 (a) Binary image A. (b) Binary image B. (c) Complement ~A. (d) Union A | B. (e) Intersec
A & B. (f) Set difference A & ~B.

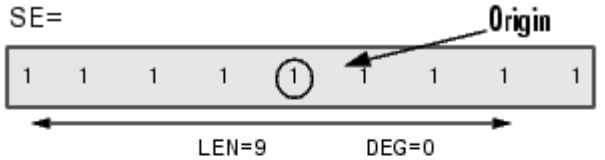
Set Operation	MATLAB Expression	Name
$A \cap B$	A & B	AND
$A \cup B$	$A \mid B$	OR
A^c	~A	NOT
$A - B$	A & ~B	DIFFERENCE

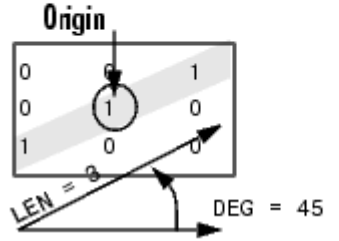
The basis of sets is to create a structured element

- Binary subset of a specific shape
- We use structured elements by passing them around the original image and performing some set operation.

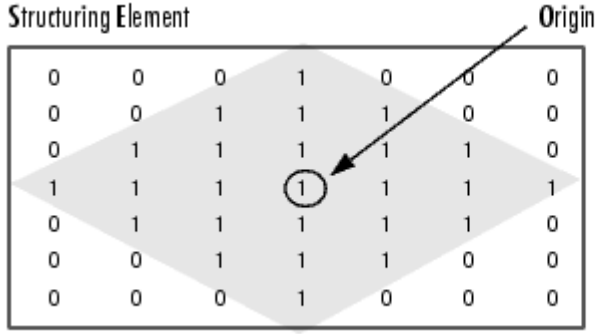


Disk





Line



Diamond

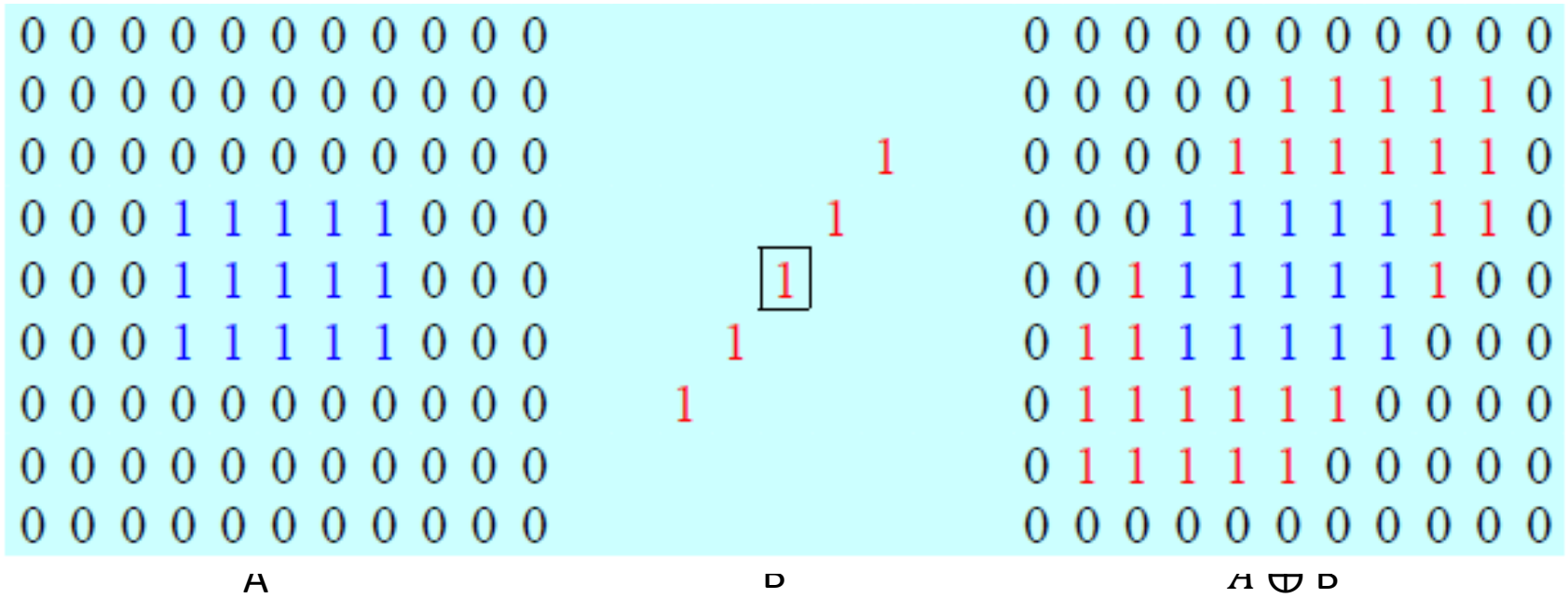
Morphological operator: dilation

- If the image has a 1 on any part of the str elem., that pixel will be one
- Extend or thicken object

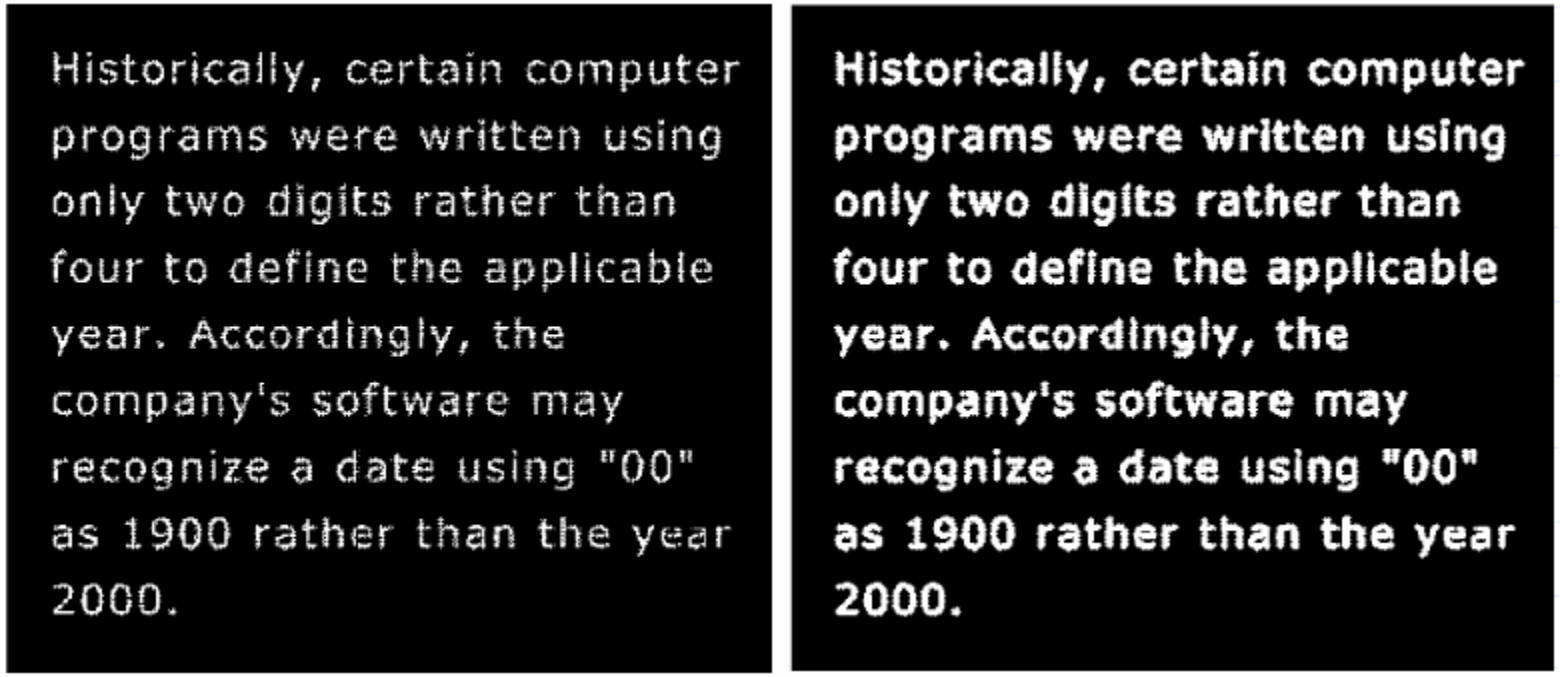
$A \oplus B$: A | B

By convention
A = image
B = structured element

$A \oplus$ B = $B \oplus$ A



Dilation examples



a b

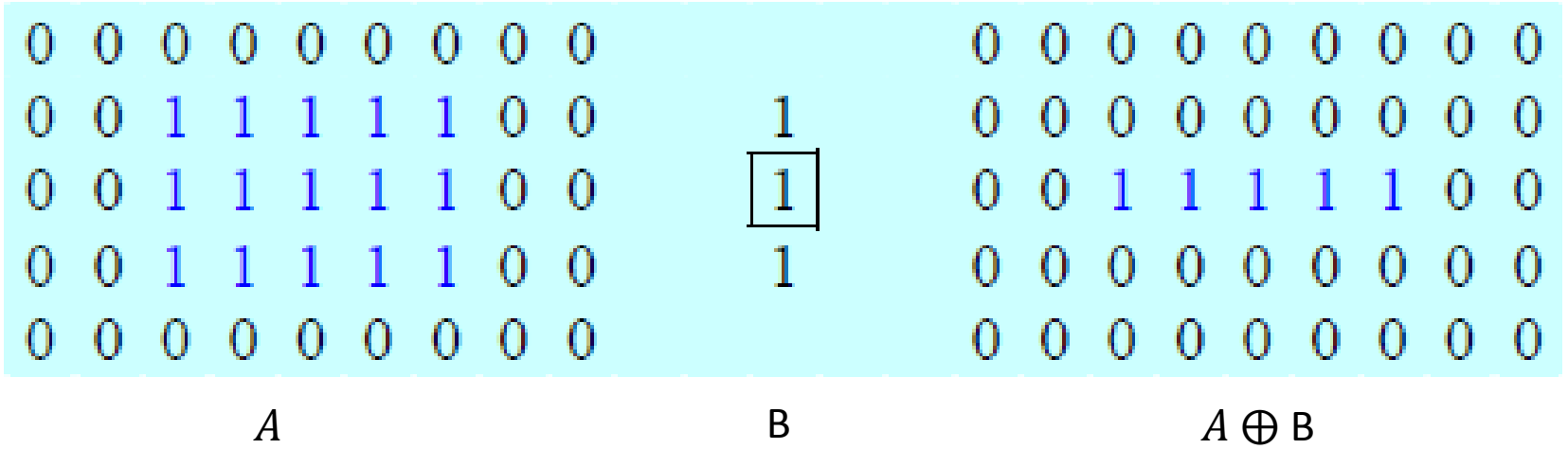
FIGURE 9.6
A simple example of dilation. (a) Input image containing broken text. (b) Dilated image.

Morphological operator: erosion

$A \ominus B$: A & B

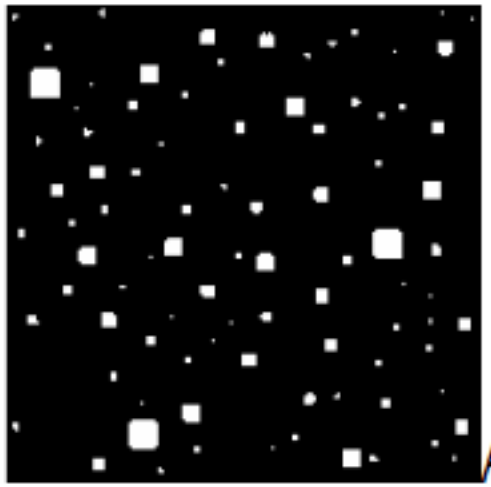
$A \ominus B \neq B \ominus A$

- If union has a 0 at any point on the st. el, that pixel will be 0
- Used to shrink objects
- Used to eliminate small details contaminants

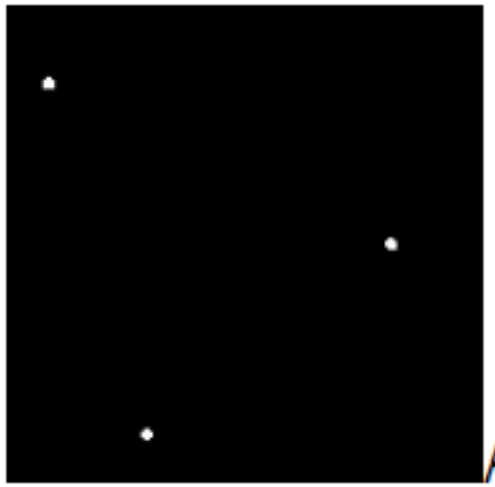


A B $A \oplus$ B

Erosion examples

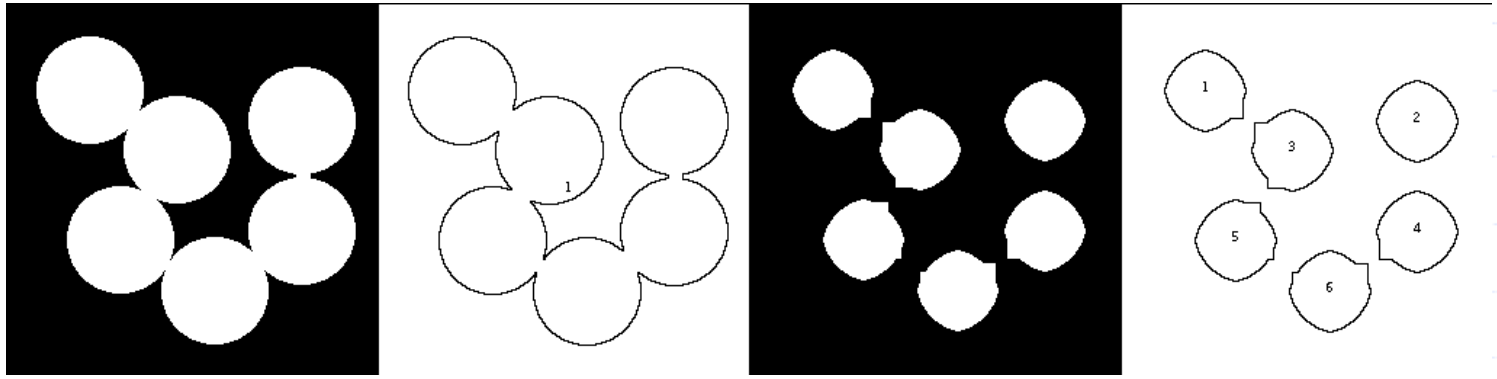


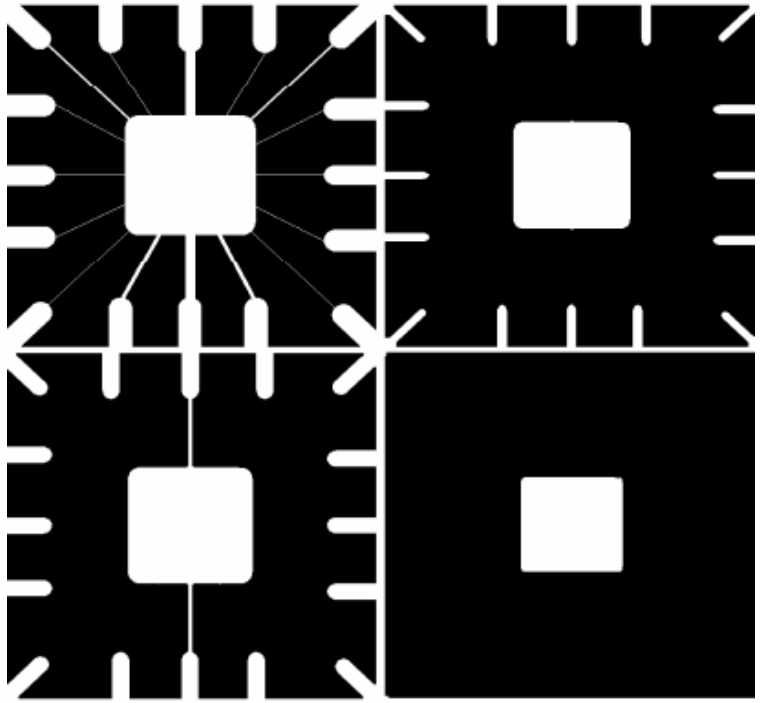
A



A1

Remove small objects, or separate objects of interest.



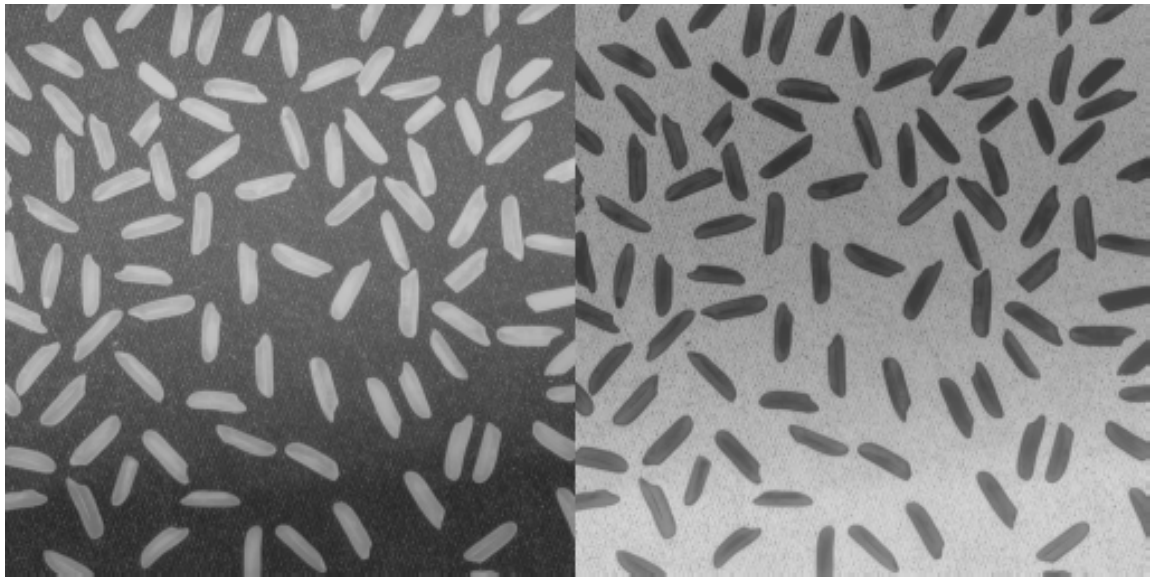


a b
c d

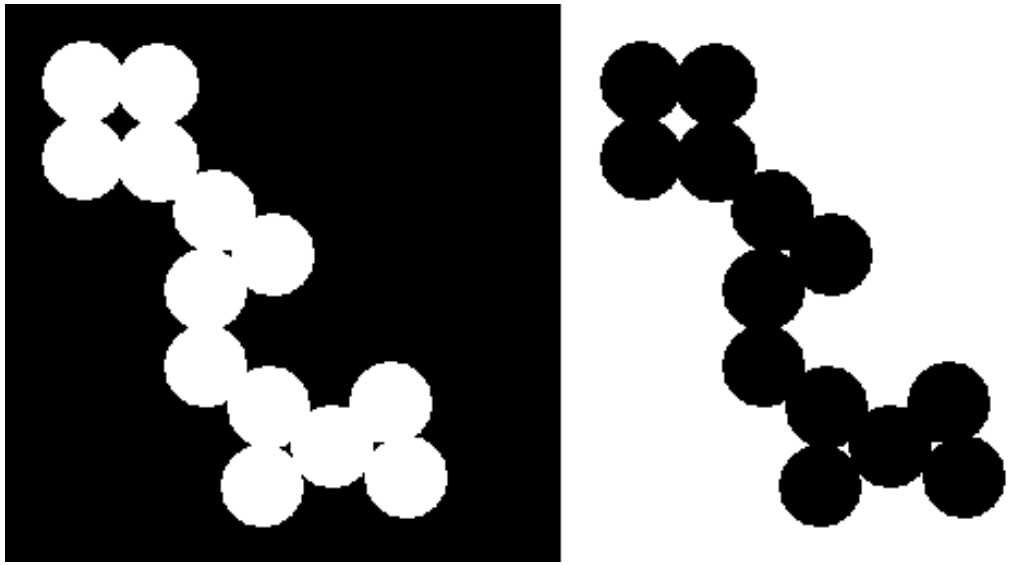
FIGURE 9.8 An illustration of erosion.
(a) Original image.
(b) Erosion with a disk of radius 10.
(c) Erosion with a disk of radius 5.
(d) Erosion with a disk of radius 20.

Complement image

- Exchange lights and darks. Works on binary, grayscale, and rgb images



~A



Combinations of operators

- Dilation and erosion are most often used in combinations of operators. The most common are opening and closing. Whole host of different morphological operators for different reasons.

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

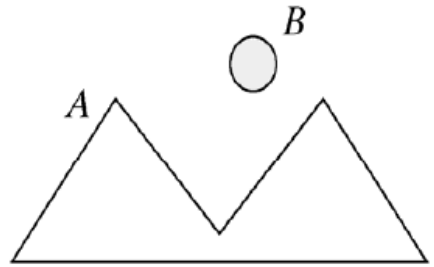
Opening: Erosion followed by dilation

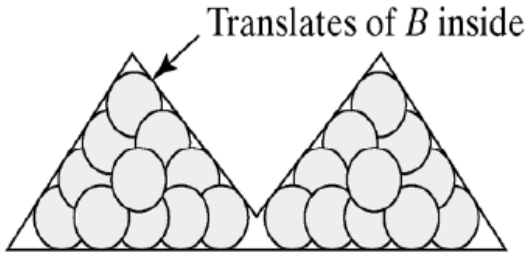
$$(A \bullet B) = (A \oplus B) \ominus B$$

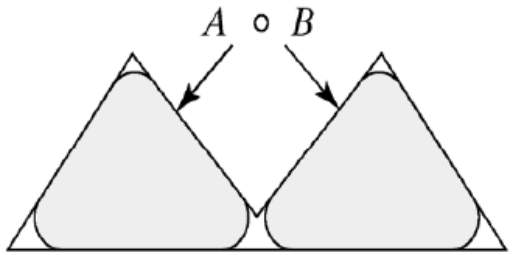
Closing: Dilation followed by erosion

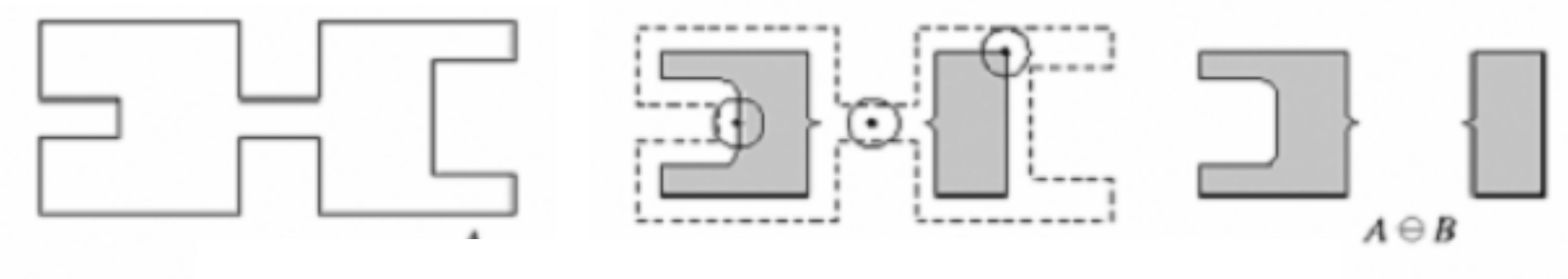
Opening

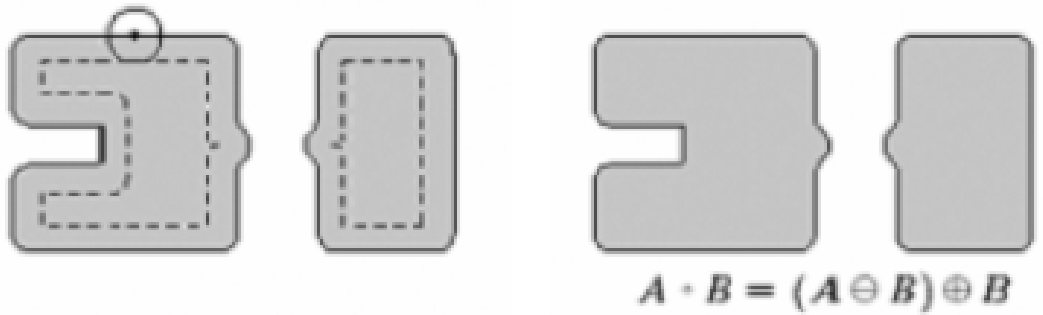
- Smooths contours, eliminates small and thin protrusions
- Erosion followed by dilation
- Union of all translation of B (strel) that fit entirely within A







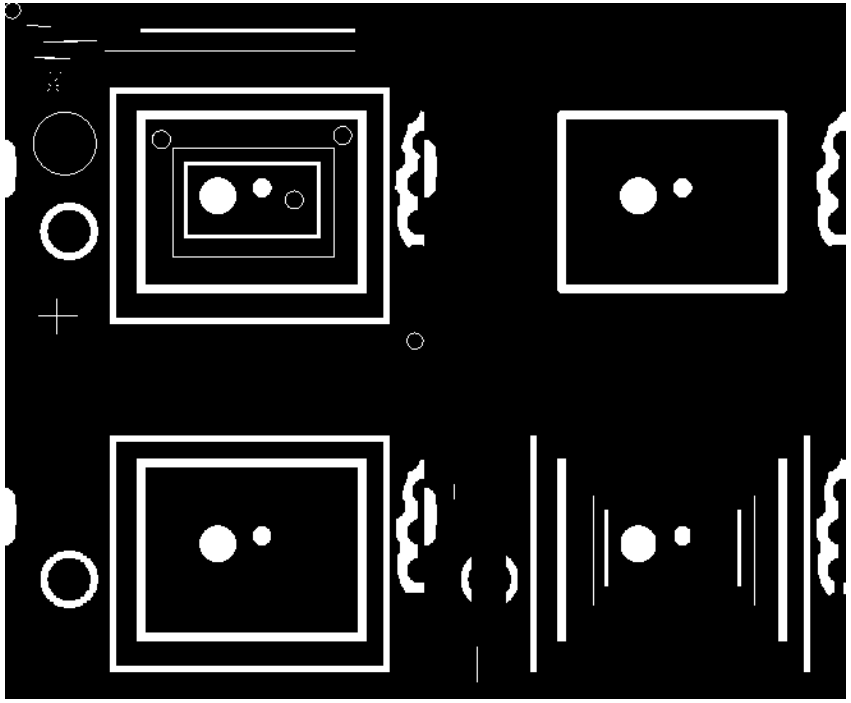




imopen examples

Original

Disk radius 4

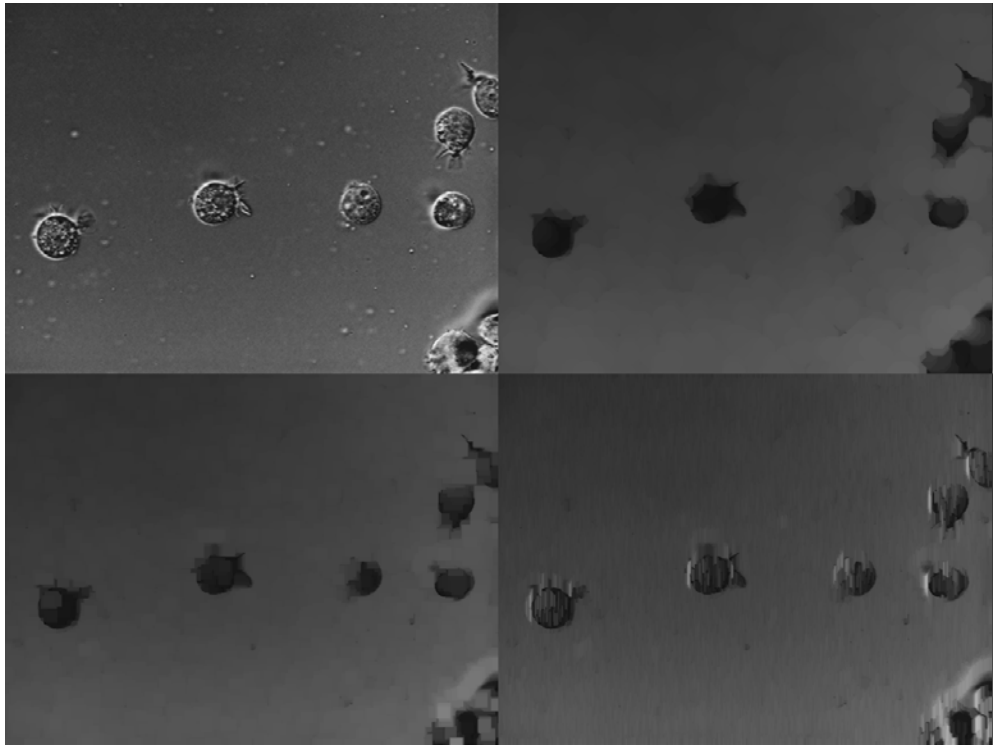


Square size 5

Vertical line length 8

Original

Disk radius 15

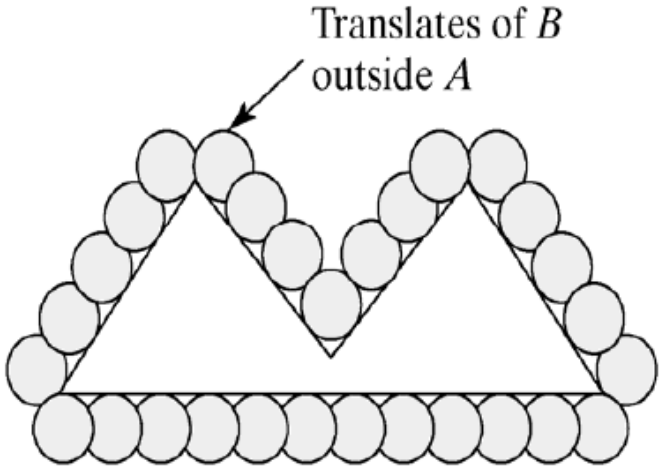


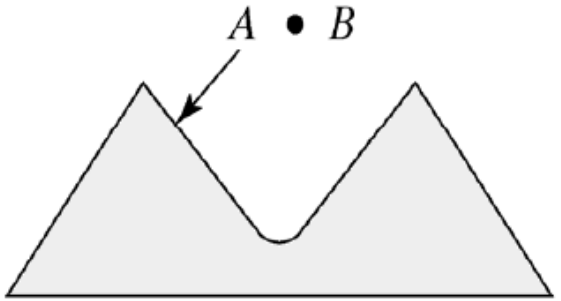
Square size 15

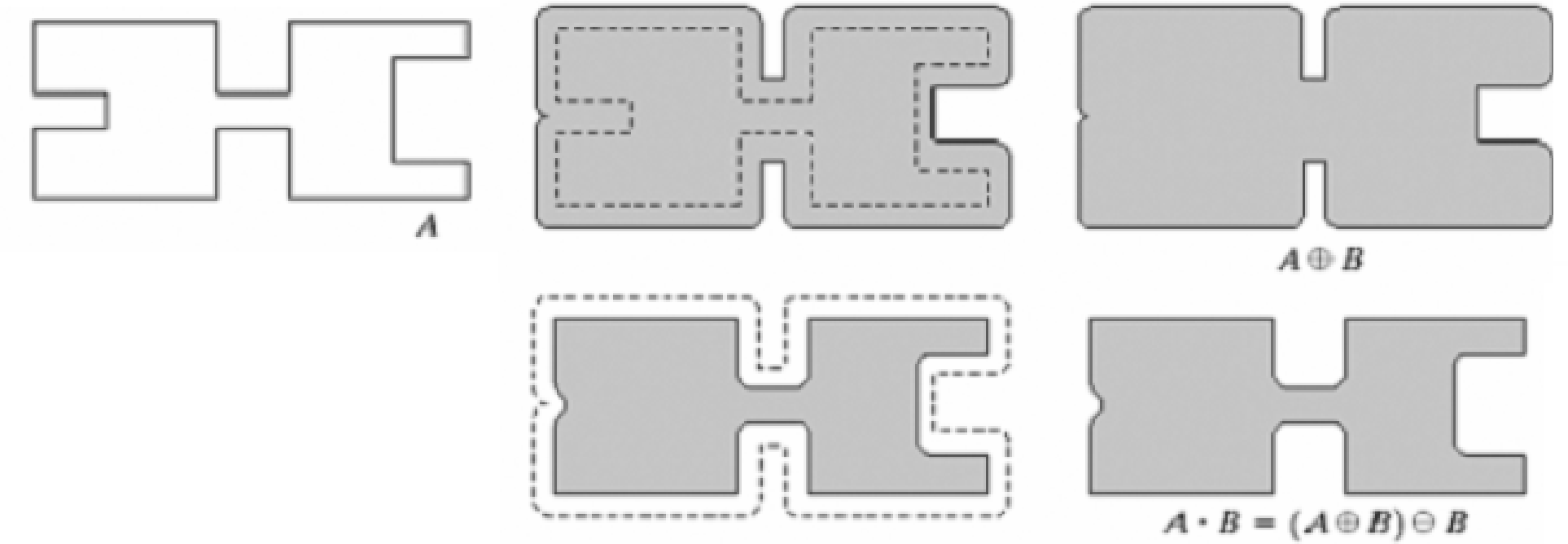
Vertical line length 15

imclose

- Smooths contours
- Fuses narrow braks and thin gulfs
- Eliminates small holes



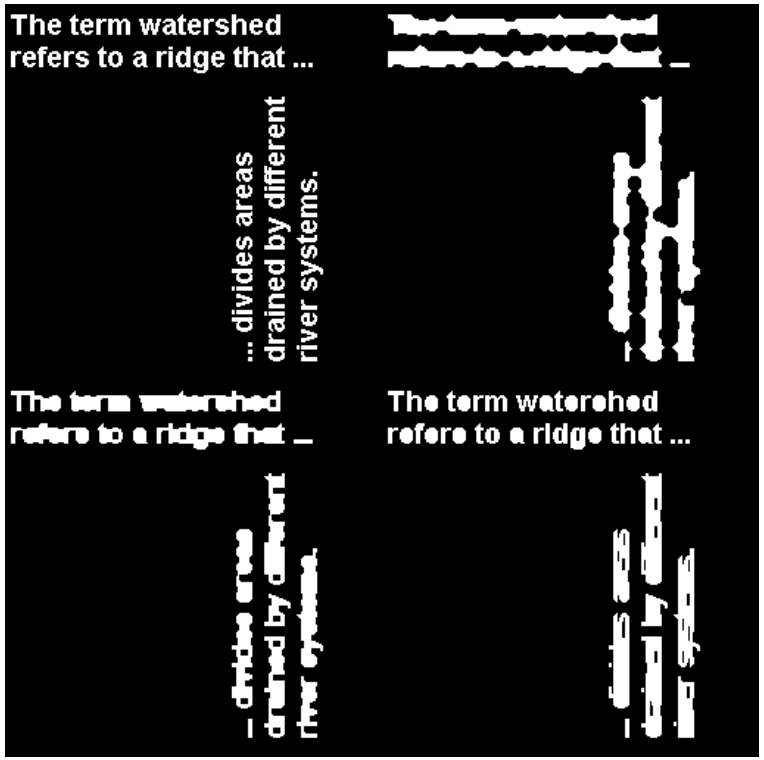




imclose examples

Original

Disk radius 5

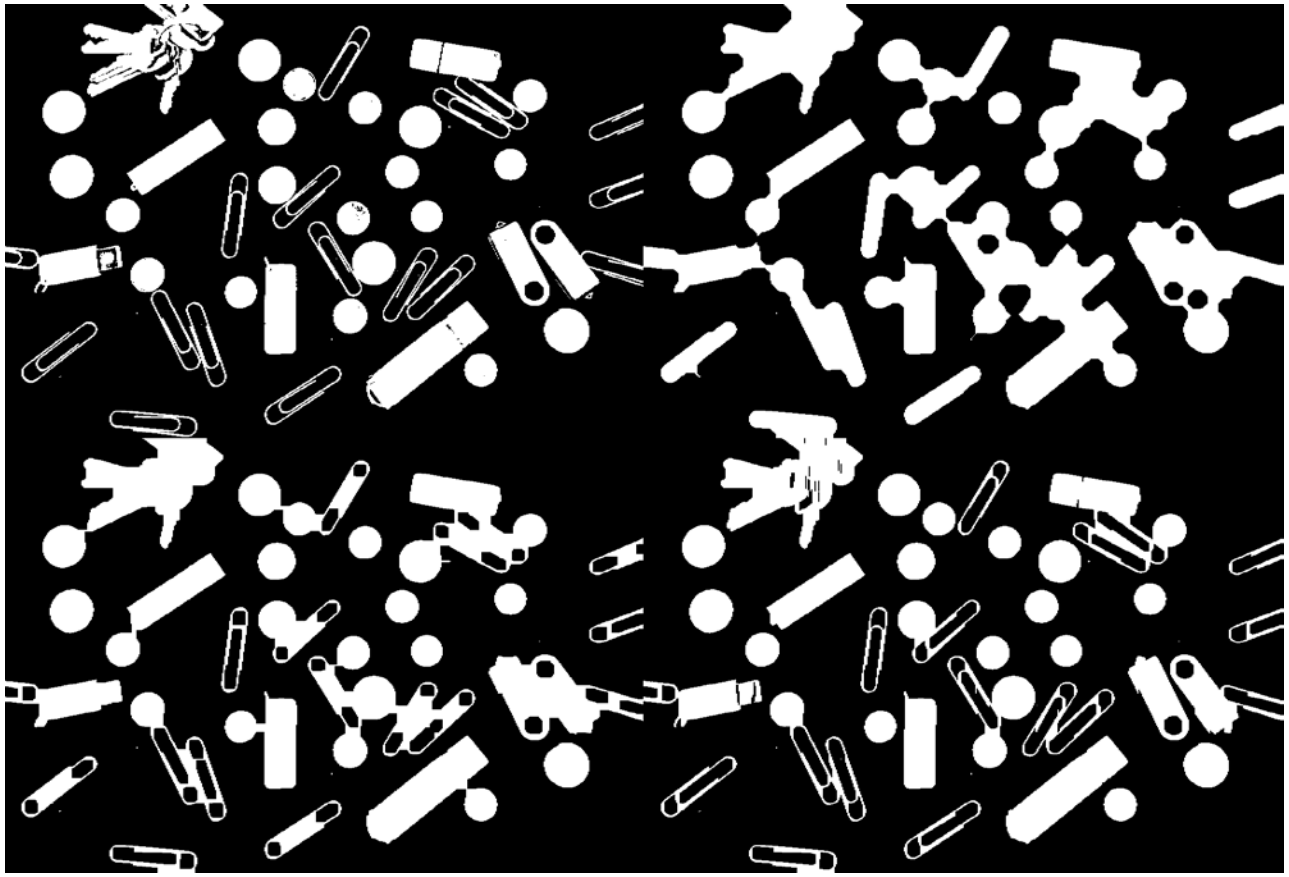


Square size 4

Vertical line length 5

Original

Disk radius 15



Square size 15

Vertical line length 15

Hit and miss processing

- Used to find very specific configuration of pixels

$$A \otimes B = (A \ominus B_1) \cap (A^c \ominus B_2)$$

$$\begin{matrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{matrix} \rightarrow \quad B_1 \begin{matrix} & 1 & \\ 1 & \boxed{1} & 1 \\ & 1 & \end{matrix} \qquad B_2 \begin{matrix} 1 & & 1 \\ & \square & \\ 1 & & 1 \end{matrix}$$

A:

$$\begin{matrix} 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&1&1&1&1&0&0 \\ 0&0&1&0&0&0&0&0&0&0&0&0&0 \\ 0&1&1&1&0&1&0&0&0&1&1&0&0 \\ 0&0&1&0&1&1&1&0&0&1&1&1&0 \\ 0&0&0&0&0&1&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0 \end{matrix}$$

$A \ominus B_1$:

$$\begin{matrix} 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0 \end{matrix}$$

A^c:

$$\begin{matrix} 1&1&1&1&1&1&1&1&1&1&1&1&1&1 \\ 1&1&0&1&1&1&1&0&0&0&0&1&1 \\ 1&1&0&1&1&1&1&1&1&1&1&1&1 \\ 1&0&0&0&1&0&1&1&1&0&0&1&1 \\ 1&1&0&1&0&0&0&1&1&0&0&0&1 \\ 1&1&1&1&1&0&1&1&1&1&0&1&1 \\ 1&1&1&1&1&1&1&1&1&1&1&1&1 \end{matrix}$$

$A^c \ominus B_2$:

$$\begin{matrix} 1&0&1&0&1&1&0&0&0&0&0&0&0&1 \\ 1&0&1&0&1&1&1&1&1&1&1&1&1 \\ 0&0&0&0&0&1&0&0&0&0&0&0&1 \\ 1&0&1&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&1&0&0&0&0&1 \\ 1&0&1&0&0&0&0&0&0&0&0&0&0 \\ 1&1&1&1&0&1&0&1&1&0&1&0&1 \end{matrix}$$

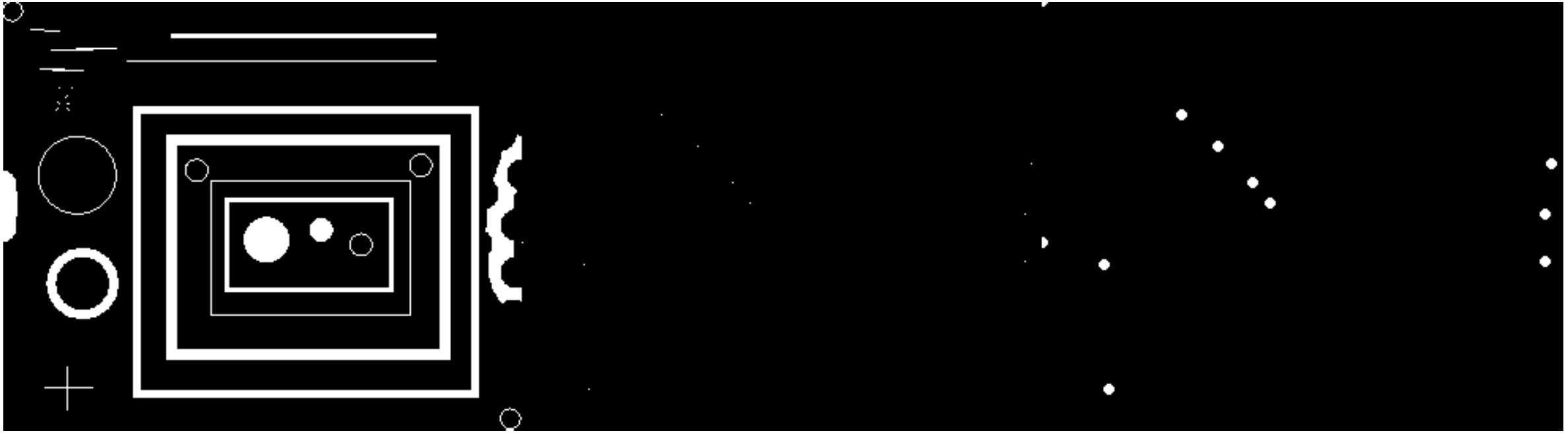
$A \otimes B_1$:

$$\begin{matrix} 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0 \end{matrix}$$

bwhitmiss examples

B1			B2		
0	**0**	**0**	**1**	**1**	**1**
0	**1**	**1**	**1**	**0**	**0**
0	**1**	**0**	**1**	**0**	**0**

Look for left hand, upper corners.



Original image

Hit B1, miss B2

Dilated for clarity

On to Matlab…