Morphological Image Processing

Preview

- "***Morphology*** " – a branch in biology that deals with the **form and structure** of animals and plants.
- "***Mathematical Morphology***" – as a tool for **extracting image components**, that are useful in the **representation and description of region shape**
- **What are the applications of Morphological Image Filtering?**
  - ❖ boundaries extraction
  - ❖ skeletons
  - ❖ convex hull
  - ❖ morphological filtering
  - ❖ thinning
  - ❖ Pruning
- The language of mathematical morphology is – **Set theory**.
- Unified and powerful approach to numerous image processing problems

Sets in mathematical morphology represent objects in an image:

- **binary image** (0 = black, 1 = white) :

the element of the set is the coordinates (x,y) of pixel belong to the object $Z2$

- **gray-scaled image** :

the element of the set is the coordinates (x,y) of pixel belong to the object and the gray levels $Z3$

Morphological operation

- It is a collection of non-linear operations related to the shape or morphology of features in an image.
- ie , we process images according to its shape
- 2 fundamental operations
  - Dilation
  - Erosion

DILATION AND EROSION

- Dilation adds pixels to the boundaries of objects in an image
- Erosion removes pixels on object boundaries

Structuring Element

A morphological operation is based on the use of a filter-like binary pattern called the structuring element of the operation. Structuring element is represented by a matrix of 0s and 1s; for simplicity, the zero entries are often omitted.

<u>Symmetric with respect to its origin:</u>

<u>Lines:</u>

$$
\begin{array}{|c|c|c|c|c|}
\hline
0 & 0 & 0 & 0 & 1 \\
\hline
0 & 0 & 0 & 1 & 0 \\
\hline
0 & 0 & \boxed{1} & 0 & 0 \\
\hline
0 & 1 & 0 & 0 & 0 \\
\hline
1 & 0 & 0 & 0 & 0 \\
\hline
\end{array}
=
\begin{array}{ccccc}
 & & & & 1 \\
 & & & 1 & \\
 & & \boxed{1} & & \\
 & 1 & & & \\
1 & & & & \\
\end{array}
\qquad\qquad
\begin{array}{c}
1 \\
\boxed{1} \\
1 \\
\end{array}
$$

<u>Diamond:</u>

$$
\begin{array}{ccc}
0 & 1 & 0 \\
1 & \boxed{1} & 1 \\
0 & 1 & 0 \\
\end{array}
$$

<u>Non-symmetric:</u>

$$
\begin{array}{ccccccc}
 & & & & & & 1 \\
1 & 1 & \boxed{1} & 1 & 1 & 1 & \\
1 & 1 & & & & & \\
1 & & & & & & \\
\end{array}
\xrightarrow{\text{Reflection on origin}}
\begin{array}{ccccccc}
 & & & & & & 1 \\
 & & & & & 1 & 1 \\
 & 1 & 1 & 1 & \boxed{1} & 1 & 1 \\
1 & & & & & & \\
\end{array}
$$

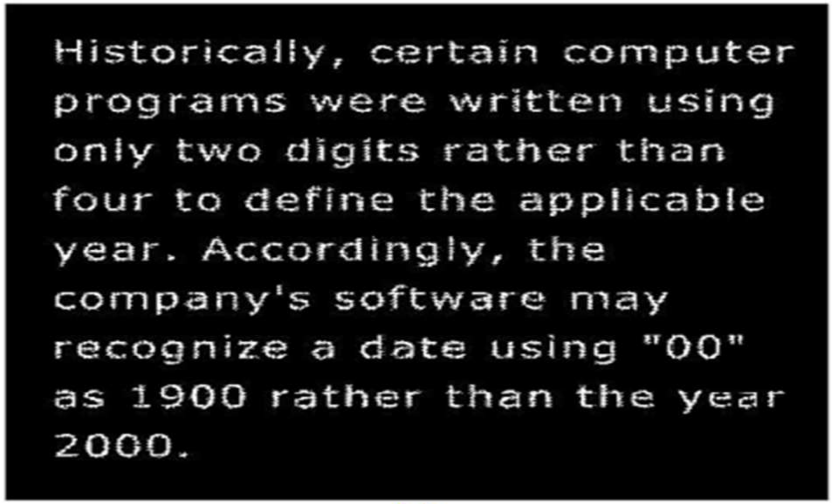
Dilation

Dilation is an operation used to grow or thicken objects in binary images. The dilation of a binary image A by a structuring element B is defined as:

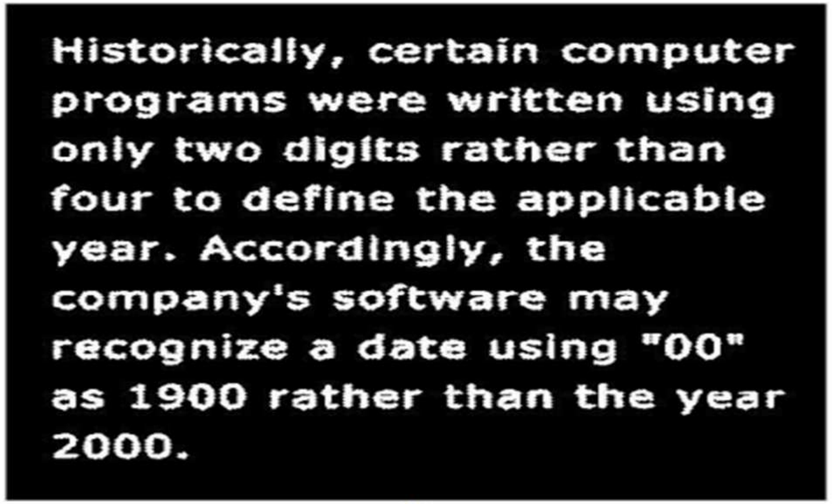
$$A \oplus B = \{z : (\hat{B})_z \cap A \neq \emptyset\}$$

This equation is based on obtaining the reflection of B about its origin and translating (shifting) this reflection by z. Then, the dilation of A by B is the set of all structuring element origin locations where the reflected and translated B overlaps with A by at least one element.

Dilation can be used for bridging gaps, for example, in broken/unclear characters as shown in the figure below.



(a)



(b)

Figure 11.3 (a) Broken-text binary image. (b) Dilated image.

- Miss ➔ No changes
- Hit ➔ at least one pixel matches =>The origin is replaced by 1

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

Input matrix

1	1	1

Structuring element

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

Dilated matrix

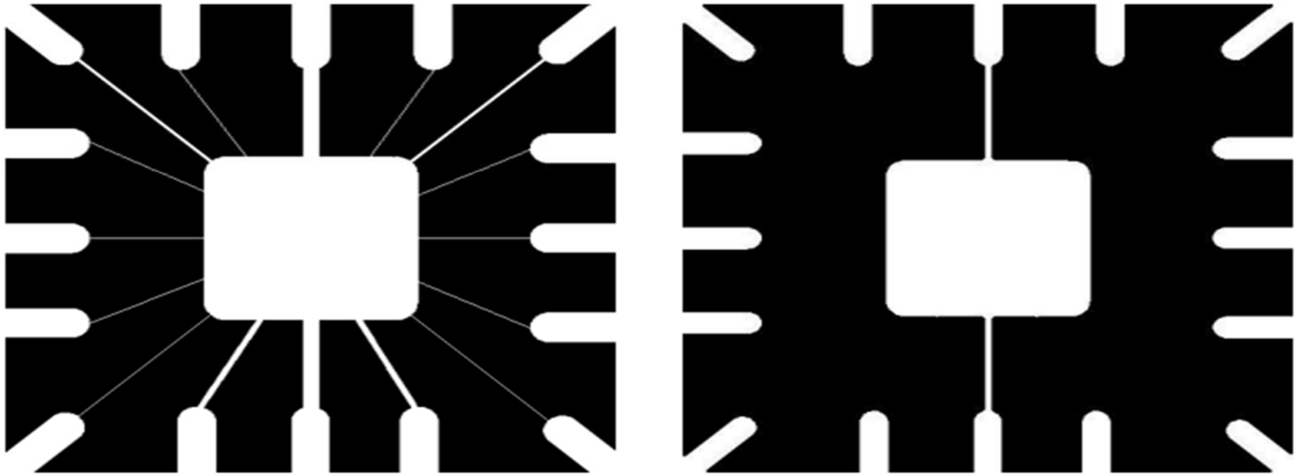
Erosion

Erosion is used to shrink or thin objects in binary images. The erosion of a binary image A by a structuring element B is defined as:

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

The erosion of A by B is the set of all structuring element origin locations where the translated B does not overlap with the background of A.

Erosion can be used to remove isolated features (i.e. irrelevant detail) which may include noise or thin edges as shown in the figure below.



(a) (b)

Figure 11.4 (a) Binary image. (b) Eroded image.

Example: Use the following structuring element to erode the binary image below.

$$\begin{array}{c}1\\ \boxed{1}\\ 1\end{array}$$

Structuring element

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**	**1**	0	0	0
0	0	0	**1**	**1**	**1**	**1**	**1**	**1**	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

Binary image

Solution

$A \ominus B =$

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**	**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
0	0	0	0	0	0	0	0	0	0	0	0

Combining Dilation & Erosion - Opening Morphology

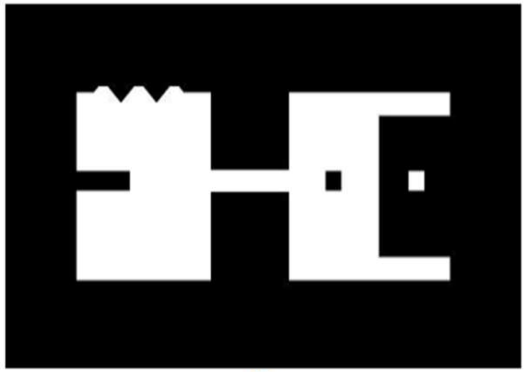
The opening operation erodes an image and then dilates the eroded image using the same structuring element for both operations, i.e.

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

where A is the original image and B is the structuring element.

The opening operation is used to remove regions of an object that cannot contain the structuring element, smooth objects contours, and breaks thin connections as shown in the figure below.

(a)

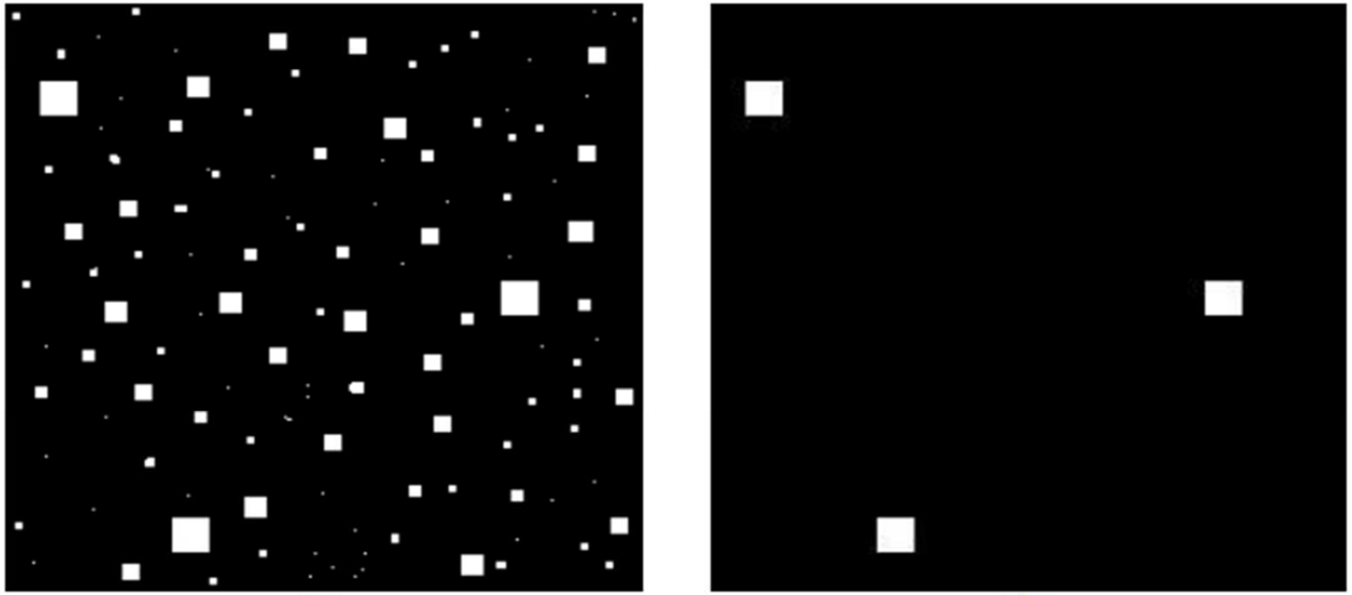


(b)

(c)

Figure 11.5 (a) Original binary image. (b) Result of opening with square structuring element of size 10 pixels. (c) Result of opening with square structuring element of size 20 pixels.

The opening operation can also be used to remove small objects in an image while preserving the shape and size of larger objects as illustrated in the figure below.



(a) (b)

Figure 11.6 (a) Original binary image. (b) Result of opening with square structuring element of size 13 pixels.

Combining Dilation & Erosion - Closing Morphology

The closing operation dilates an image and then erodes the dilated image using the same structuring element for both operations, i.e.

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

where A is the original image and B is the structuring element.

The closing operation fills holes that are smaller than the structuring element, joins narrow breaks, fills gaps in contours, and smoothes objects contours as shown in the figure below.

(a)

(b)

Figure 11.7 (a) Result of closing with square structuring element of size 10 pixels. (c) Result of closing with square structuring element of size 20 pixels.

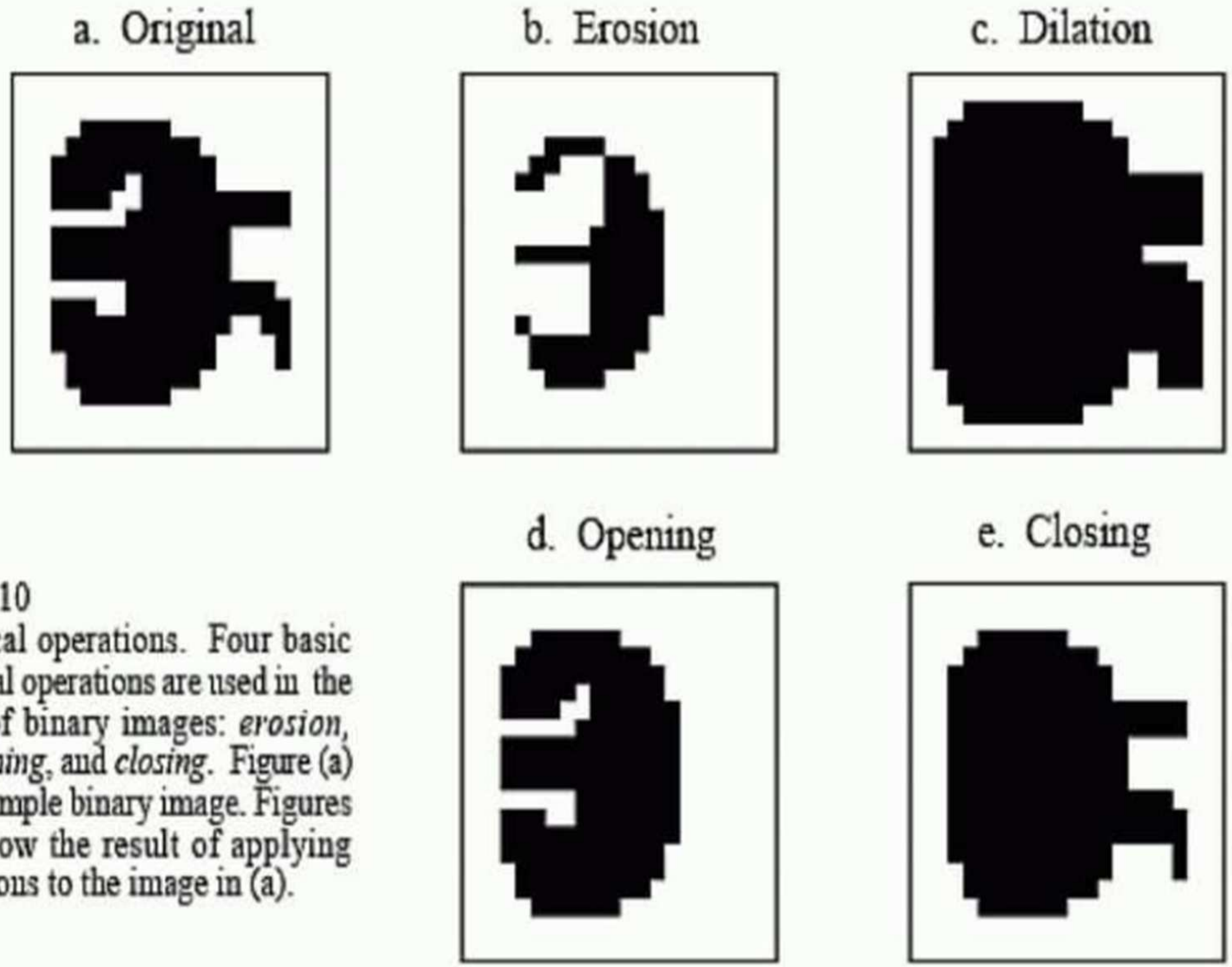


FIGURE 25-10
Morphological operations. Four basic morphological operations are used in the processing of binary images: *erosion*, *dilation*, *opening*, and *closing*. Figure (a) shows an example binary image. Figures (b) to (e) show the result of applying these operations to the image in (a).