Lecture 3:

Morphological Image Processing

Morphology

- The word **morphology** refers to form and structure of an object.
- "*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.
- The language of mathematical morphology is – **Set theory**.
- Unified and powerful approach to numerous image processing problems.

- In binary images , the set elements are members of the 2-D integer space – **Z** . where each element *(x,y)* is a coordinate of a black (or white) pixel in the image.

Effect of Some Morphological Processing

Pre-processed Image

Image after morphological processing

After the morphological process, some noises are removed and some disconnections are filled

Binary image analysis

- Binary image analysis consists of a set of operations that are used to produce or process binary images, usually images of 0’s and 1’s where
  - 0 represents the background,
  - 1 represents the foreground.

```
000100100010000
000111100010000
000100100010000
```

Thresholding

- Binary images can be obtained by thresholding.
- Assumptions for thresholding:
  - Object region of interest has intensity distribution different from background.
  - Object pixels likely to be identified by intensity alone:
    - $intensity > a$
    - $intensity < b$
    - $a < intensity < b$
- Works OK with flat-shaded scenes or engineered scenes.
- Does not work well with natural scenes.

Mathematic Morphology

- Morphological processes on images are used to extract image components that are useful in the representation and description of region shape, such as
  - *boundaries extraction*
  - *skeletons*
  - *convex hull*
  - *morphological filtering*
  - *Thinning*
  - *Thickening*
  - *pruning*

Operations in Image Morphology

- Mathematical morphology consists of two basic operations
  - ***dilation***
  - ***erosion***

  and several composite relations that can be made of the above
  - opening
  - closing
  - conditional dilation
  - …

Pixels and neighborhoods

- In many algorithms, not only the value of a particular pixel, but also the values of its neighbors are used when processing that pixel.
- The two most common definitions for neighbors are the **4- neighbors** and the **8-neighbors** of a pixel.

	N	
W	*	E
	S	

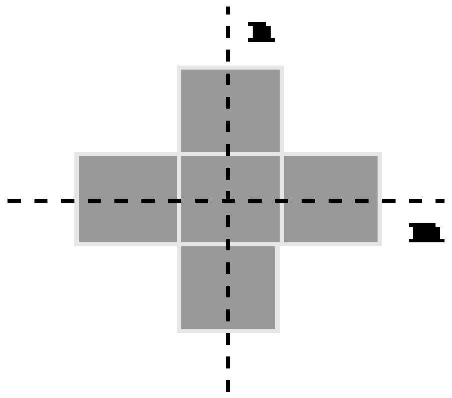
a) four-neighborhood N_4

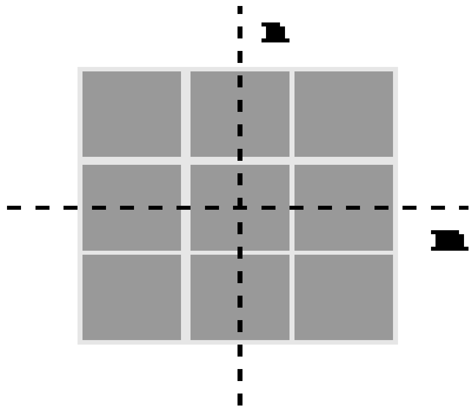
NW	N	NE
W	*	E
SW	S	SE

b) eight-neighborhood N_8

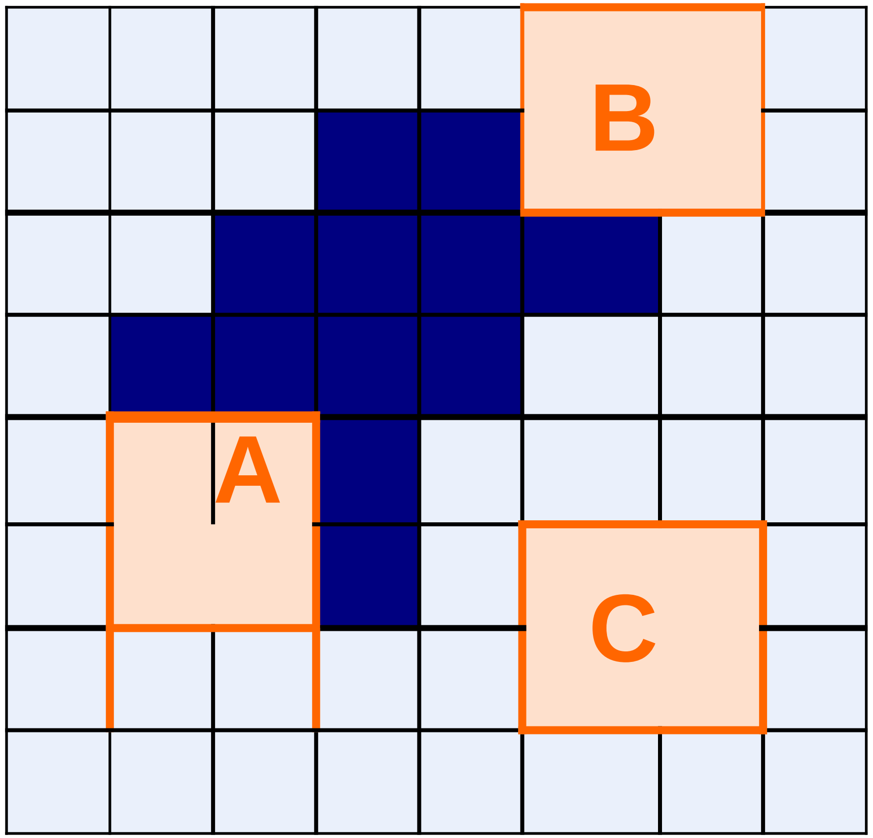
Structural Element

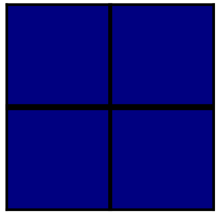
- The two most common structuring elements (given a Cartesian grid) are the 4-connected and 8-connected sets, N_4 and N_8.





Structuring Elements, Hits & Fits





Structuring Element

Fit: All *on pixels* in the structuring element cover *on pixels* in the image

Hit: Any *on pixel* in the structuring element covers an *on pixel* in the image

All morphological processing operations are based on these simple ideas

Structuring Elements

Morphological operations are mainly defined based on the structure and intensity (0 or 1) of each pixel in the structure.

- Structuring elements can be any size and make any shape
- Mostly rectangular structuring elements with their origin at the middle pixel is used

1	1	1
1	**1**	1
1	1	1

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

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

Fundamental Operations

Basic morphological algorithms are done based on a decision whether to extend or shrink part of an image;

- These operations are very similar with the process of spatial filtering
- The structuring element is moved across every pixel in the original image to give a pixel in a new processed image
- The value of this new pixel depends on the operation performed
- There are two basic morphological operations:

1. ***erosion*** *and*
2. ***dilation***

Definitions – Erosion and Dilation

- ***While either set A or B can be thought of as an "image", A is usually considered as the image and B is called a structuring element. The structuring element is to mathematical morphology what the convolution kernel is to linear filter theory.***

- ***Dilation***, in general, causes objects to dilate or grow in size.
- In the contrary, ***erosion*** causes objects to shrink.
- The amount and the way that they grow or shrink depend upon the choice of the structuring element. Dilating or eroding without specifying the structural element makes no more sense than trying to lowpass filter an image without specifying the filter.

Dilation

- **Dilation** is used for expanding an element A by using structuring element B
- Dilation of A by B and is defined by the following equation:

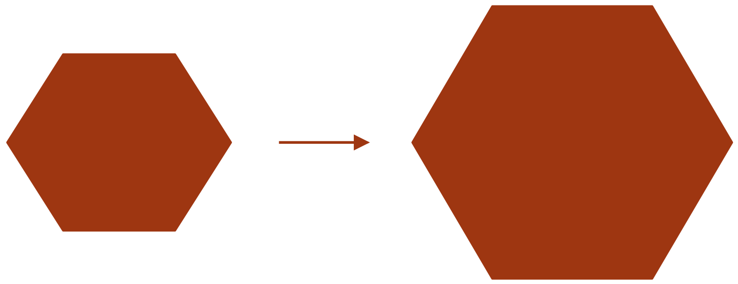
$$A \oplus B = \{z | (\hat{B})_z \cap A \neq \emptyset\}$$

- This equation is based on obtaining the reflection of B about its origin and shifting this reflection by z.
- The dilation of A by B is the set of all displacements z, such that $\hat{B}$ and A overlap by at least one element. Based on this interpretation the previous equation can be rewritten as:

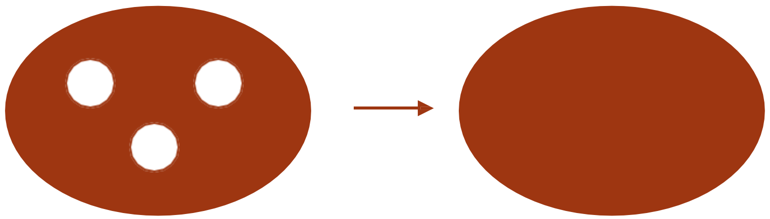
$$A \oplus B = \{z | [(\hat{B})_z \cap A] \subset A\}$$

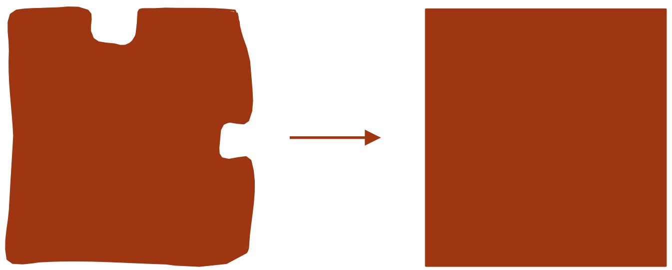
Cont..

- Dilation expands the connected sets of 1s of a binary image.
- It can be used for
  - growing features



  - filling holes and gaps





Dilation - How It Works

- To compute the dilation of a binary input image by this structuring element, we consider each of the background pixels in the input image in turn.
- For each background pixel (which we will call the input pixel) we superimpose the structuring element on top of the input image so that the origin of the structuring element coincides with the input pixel position.
  - **If at least one pixel in the structuring element coincides with a foreground pixel in the image underneath, then the input pixel is set to the foreground value.**
  - **If all the corresponding pixels in the image are background, however, the input pixel is left at the background value.**

Dilation Example

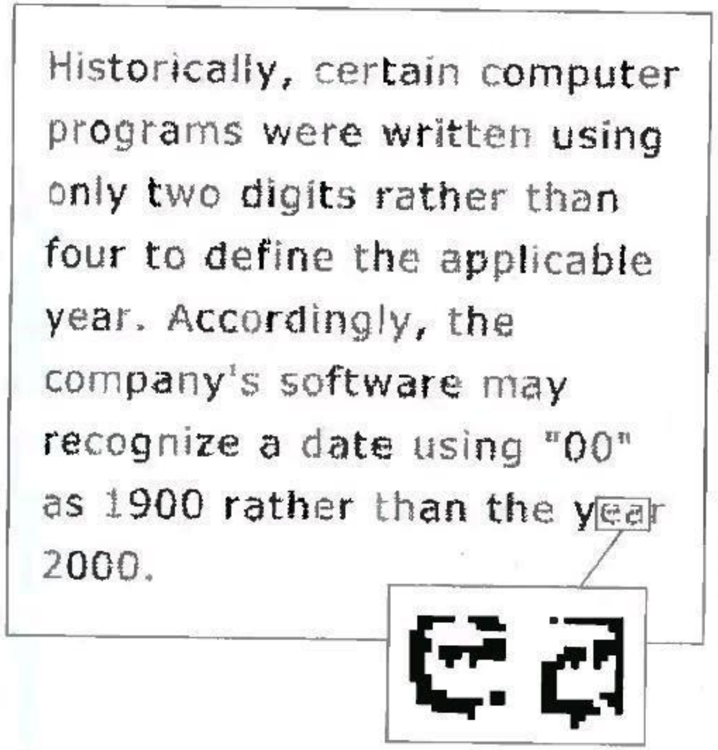
Original image

Dilation by 3*3 square structuring element

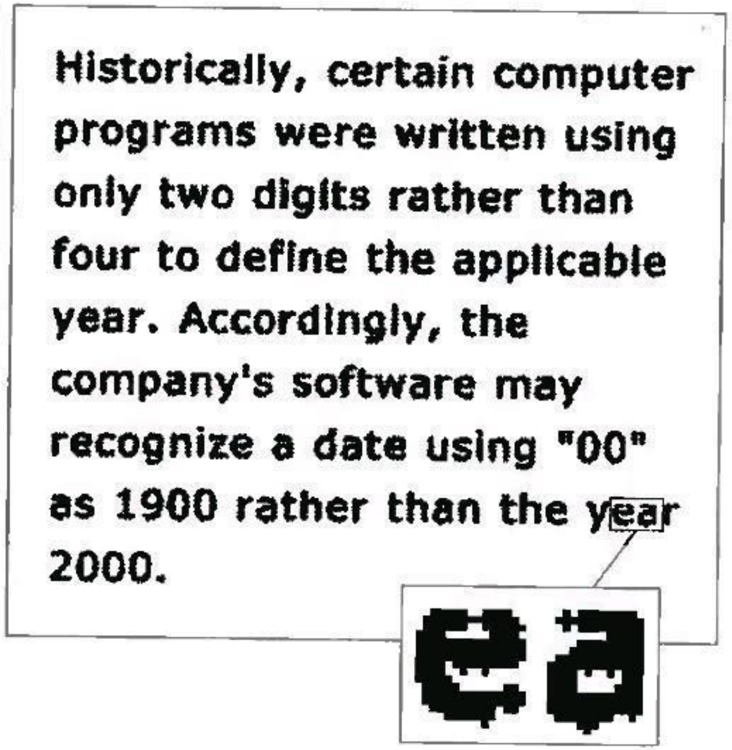
Dilation by 5*5 square structuring element

In these examples a 1 refers to a black pixel!

Dilation Example
Text Image Enhancement



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.

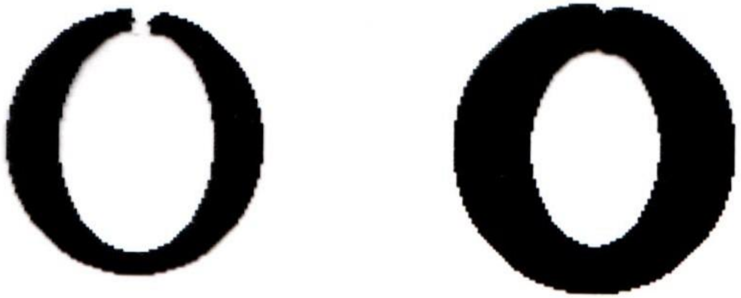


Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

0	1	0
1	1	1
0	1	0

Purpose of Dilation

Dilation can repair breaks



Dilation can repair intrusions

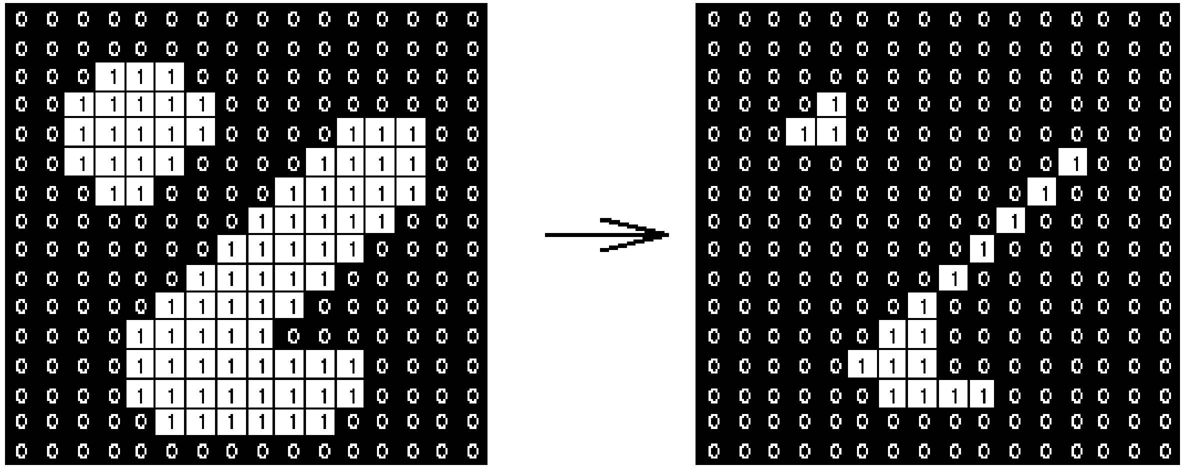
Dilation enlarges objects

Properties of Dilation

- Dilation adds pixels to the boundary of an object/part of an image;
- Number of pixels added depends on the size and type of object and the image;
- Dilation can connect parts/area that are disconnected;
- In gray level image, dilation increases the brightness of the image;

Erosion

The basic effect of the operator on a binary image is to ***erode away the boundaries of regions of foreground pixels*** (i.e. white pixels in the example). Thus areas of foreground pixels shrink in size, and holes within those areas become larger. Effect of erosion using a 3×3 square structuring element



How Erosion Works

- To compute the erosion of a binary input image by this structuring element, we consider each of the *foreground* pixels in the input image in turn. For each foreground pixel (which we will call the *input pixel*) we superimpose the structuring element on top of the input image so that the origin of the structuring element coincides with the input pixel coordinates.
  - **If for *every* pixel in the structuring element, the corresponding pixel in the image underneath is a foreground pixel, then the input pixel is left as it is.**
  - **If any of the corresponding pixels in the image are background, however, the input pixel is also set to background value.**

Erosion

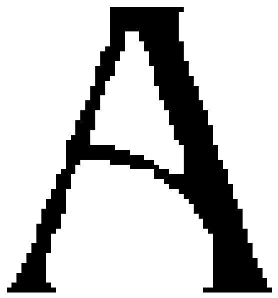
- Erosion is used for shrinking of element A by using element B
- Erosion for Sets A and B in Z^2, is defined by the following equation:

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

- This equation indicates that the erosion of A by B is the set of all points z such that B, translated by z, is combined in A.

Erosion Example

Original image

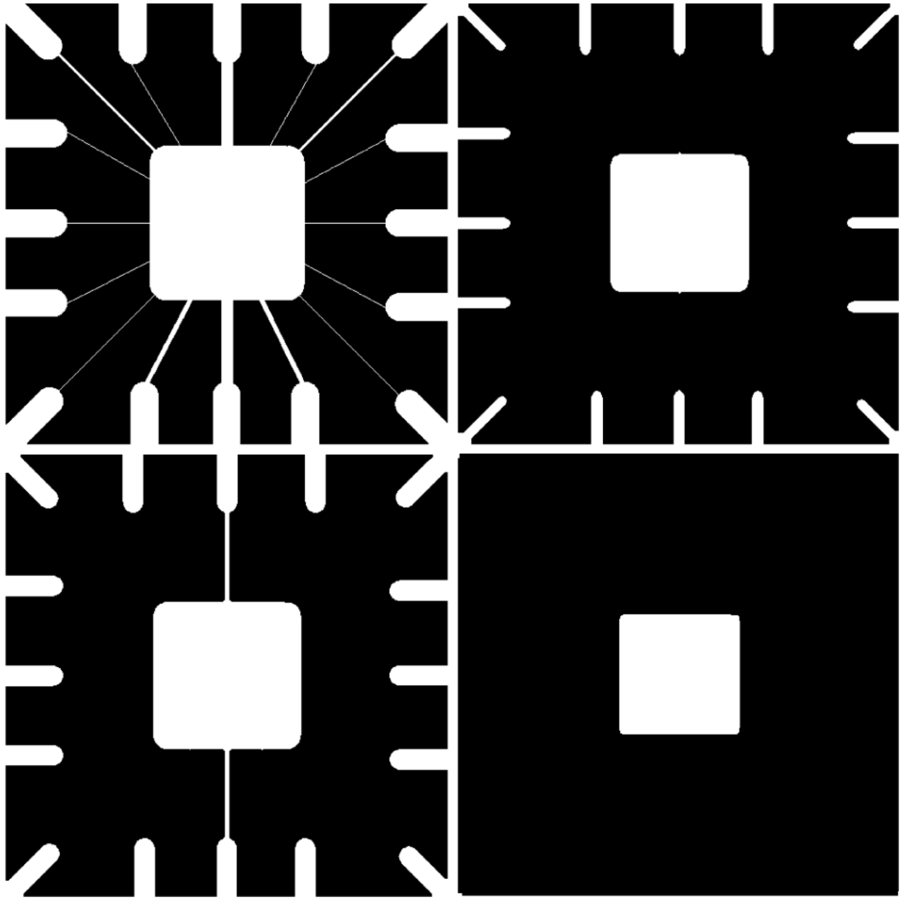


Erosion by 3*3 square structuring element

Erosion by 5*5 square structuring element

Cont..

Original image



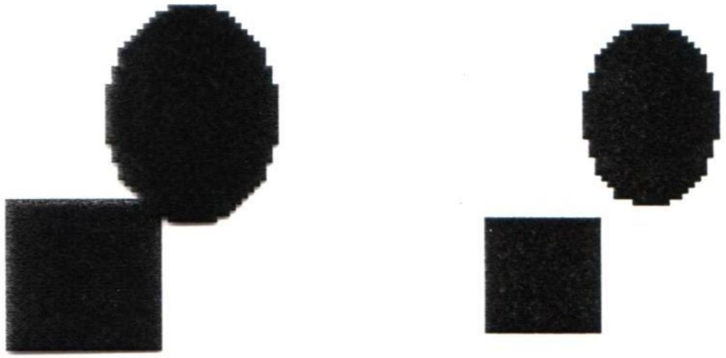
After erosion with a disc of radius 10

After erosion with a disc of radius 5

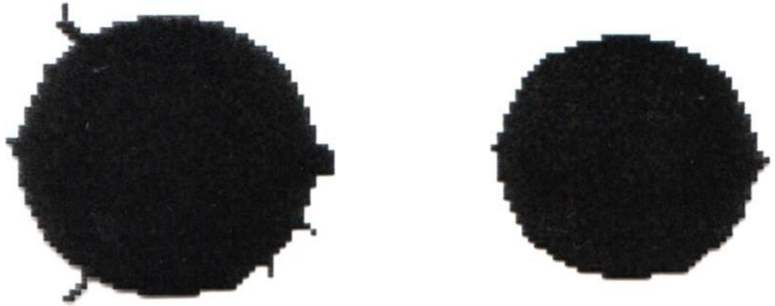
After erosion with a disc of radius 20

Purpose of Erosion

Erosion can split apart joined objects



Erosion can strip away extrusions



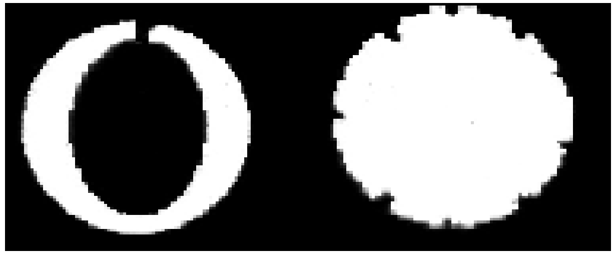
Erosion shrinks objects

Properties of Erosion

- ***Generally, erosion is the opposite of dilation***
- Erosion removes pixels from the boundary of an object/part of an image;
- Number of pixels removed depends on the size and type of object and the image;
- Erosion may separate parts/area that were connected;
- In gray level image, erosion decreases the brightness of the image;

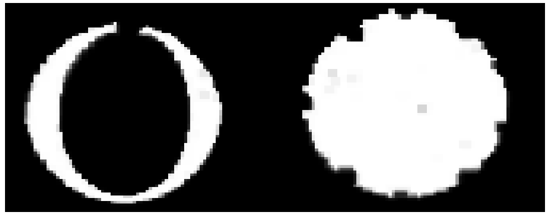
Example: Dilation and Erosion using same Structuring Element

Original



Dilated Image

Eroded Image



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

SE= 5 X 5

Opening and Closing

- Opening – smoothes contours , eliminates projection
- Closing – smoothes sections of contours, fuses narrow breaks and long thin gulfs, eliminates small holes and fills gaps in contours
- These operations are can be applied few times, but has effect only once

Opening and Closing

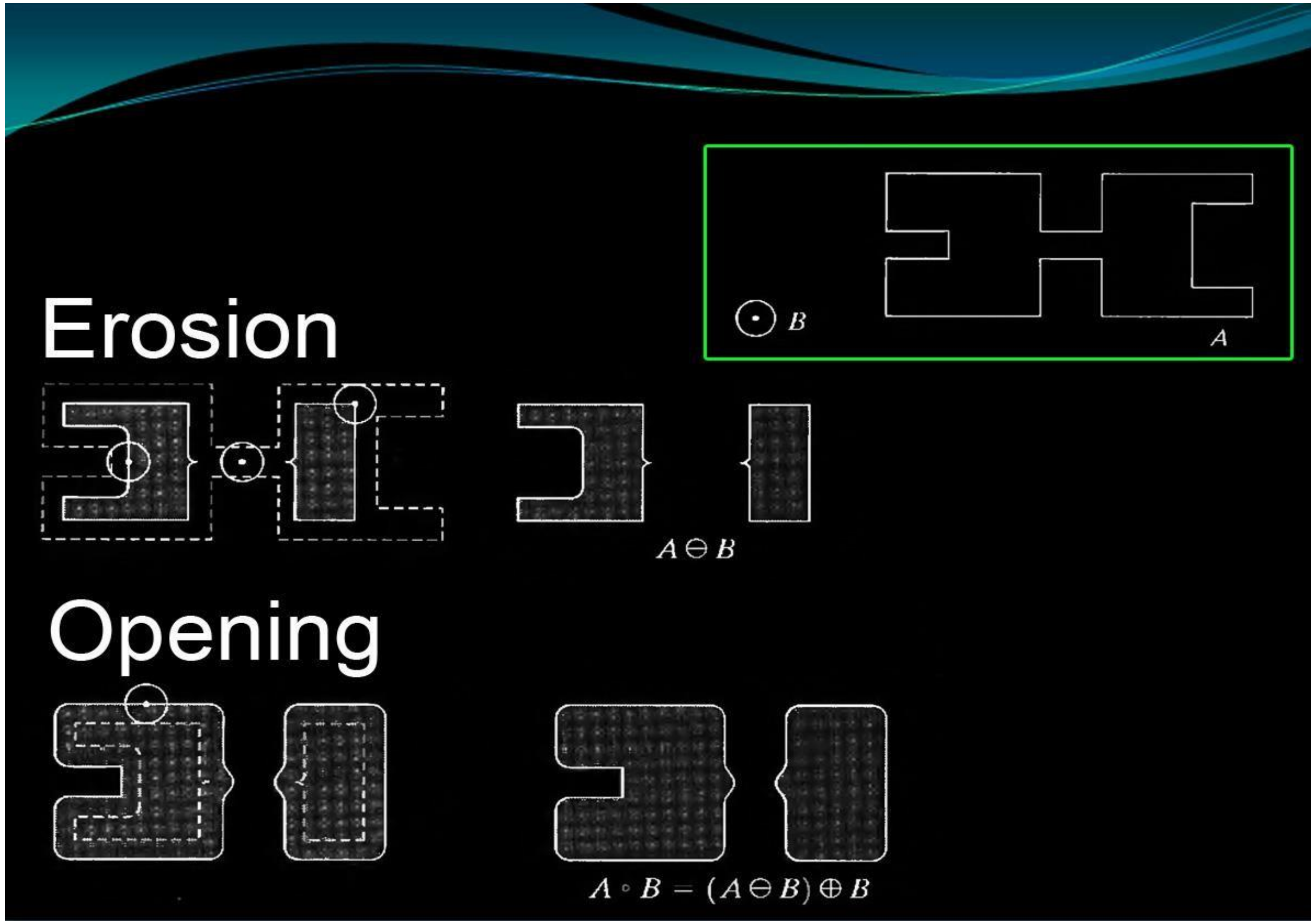
- **Opening** –
  - First – **erode** A by B, and then **dilate** the result by B
  - In other words, opening is the unification of all B objects Entirely Contained in A

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

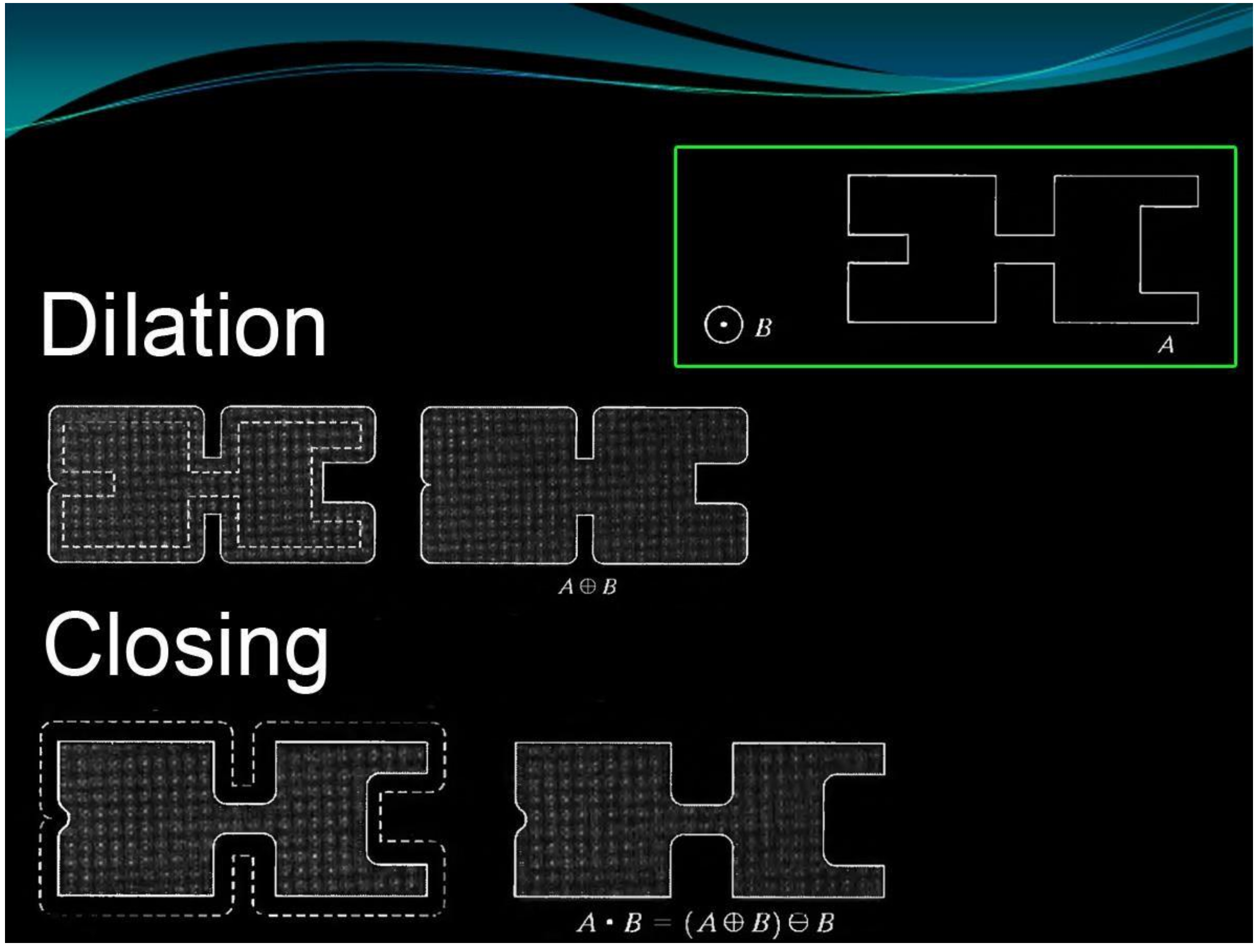
- **Closing** –
  - First – **dilate** A by B, and then **erode** the result by B
  - In other words, closing is the group of points, which the intersection of object B around them with object A – is not empty

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

Erosion & Opening



Dilation & Closing



Basic Morphological Algorithms

1. Boundary Extraction
2. Region Filling
3. Extraction of Connected Components
4. Convex Hull
5. Thinning
6. Thickening
7. Skeletons

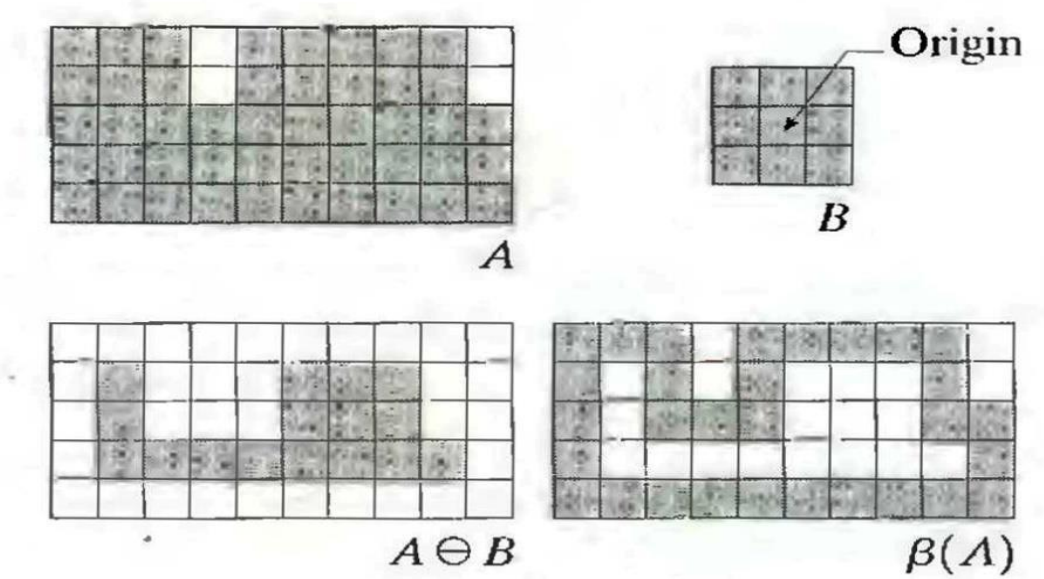
Reading Assignment

Boundary Extraction

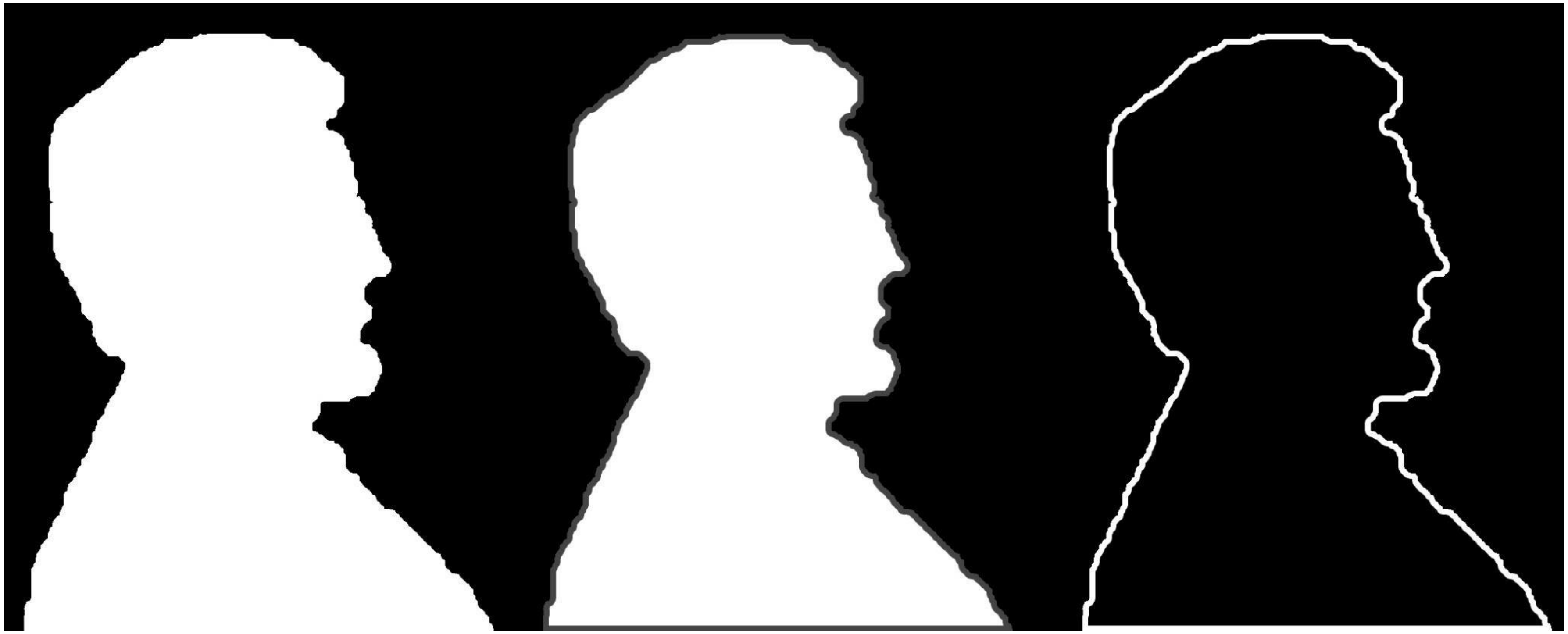
- First, ***erode*** A by B, then make ***set difference*** between A and the erosion

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

- The thickness of the contour depends on the size of constructing object – B

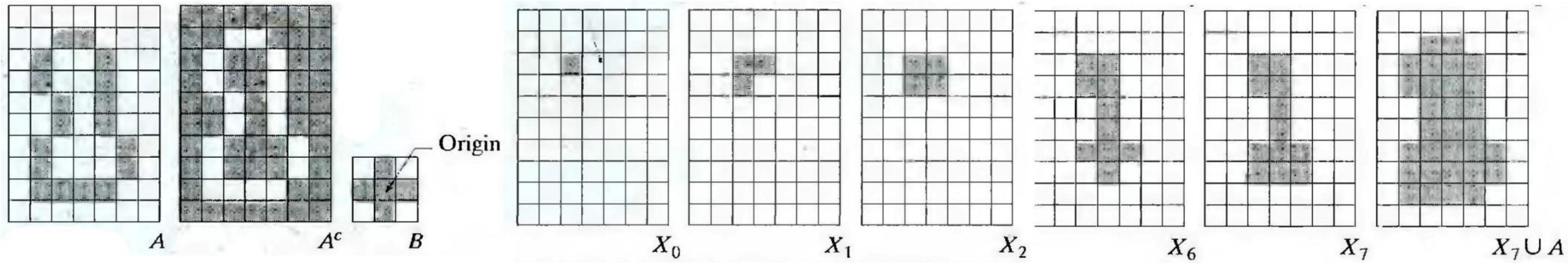


Boundary Extraction

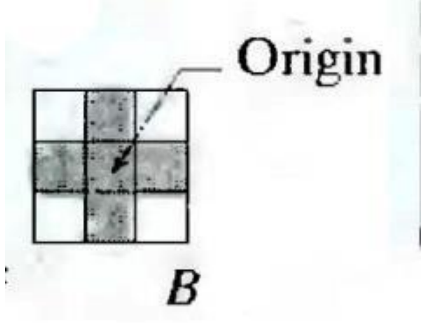


Region Filling

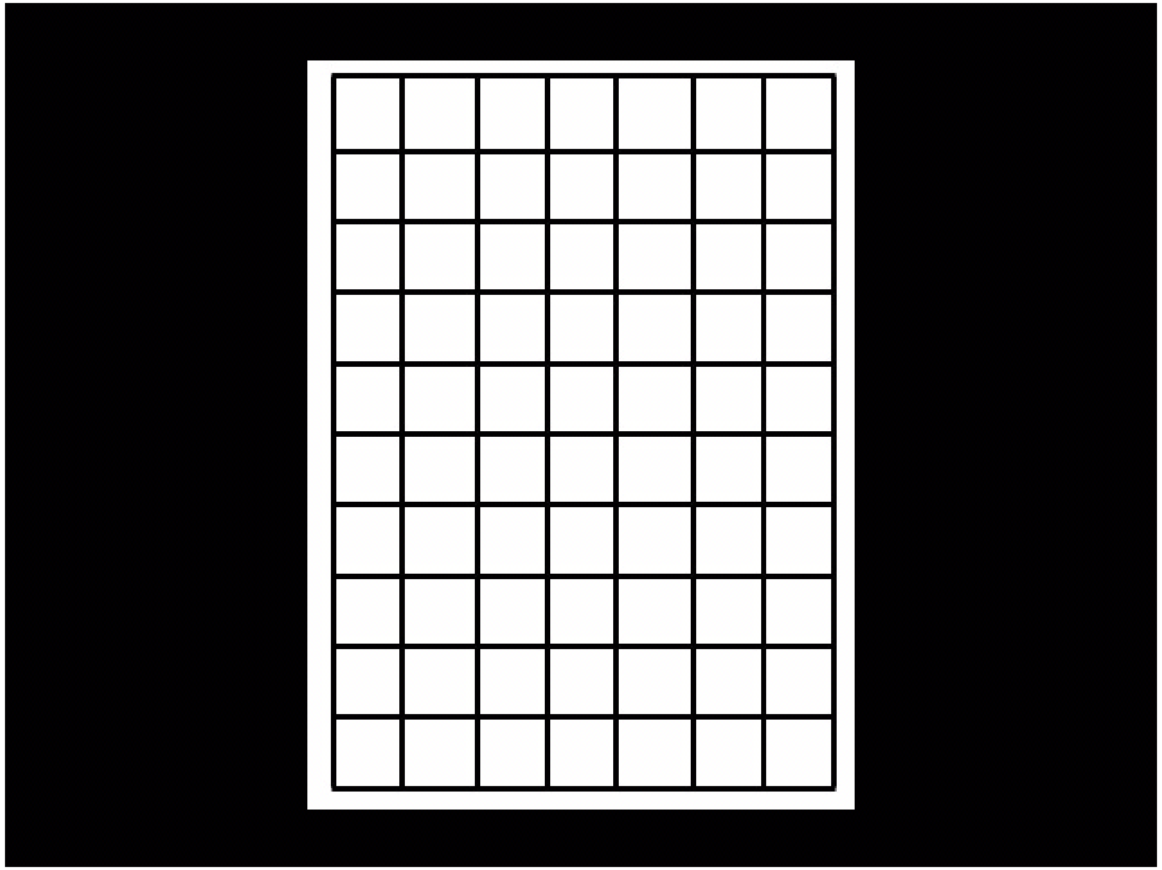
- This algorithm is based on a set of ***dilations***, ***complementation*** and ***intersections***
- p is the point inside the boundary, with the value of 1
- X(k) = (X(k-1) xor B) conjunction with complemented A
- The process stops when X(k) = X(k-1)
- The result that given by union of A and X(k), is a set contains the filled set and the boundary



Region Filling



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

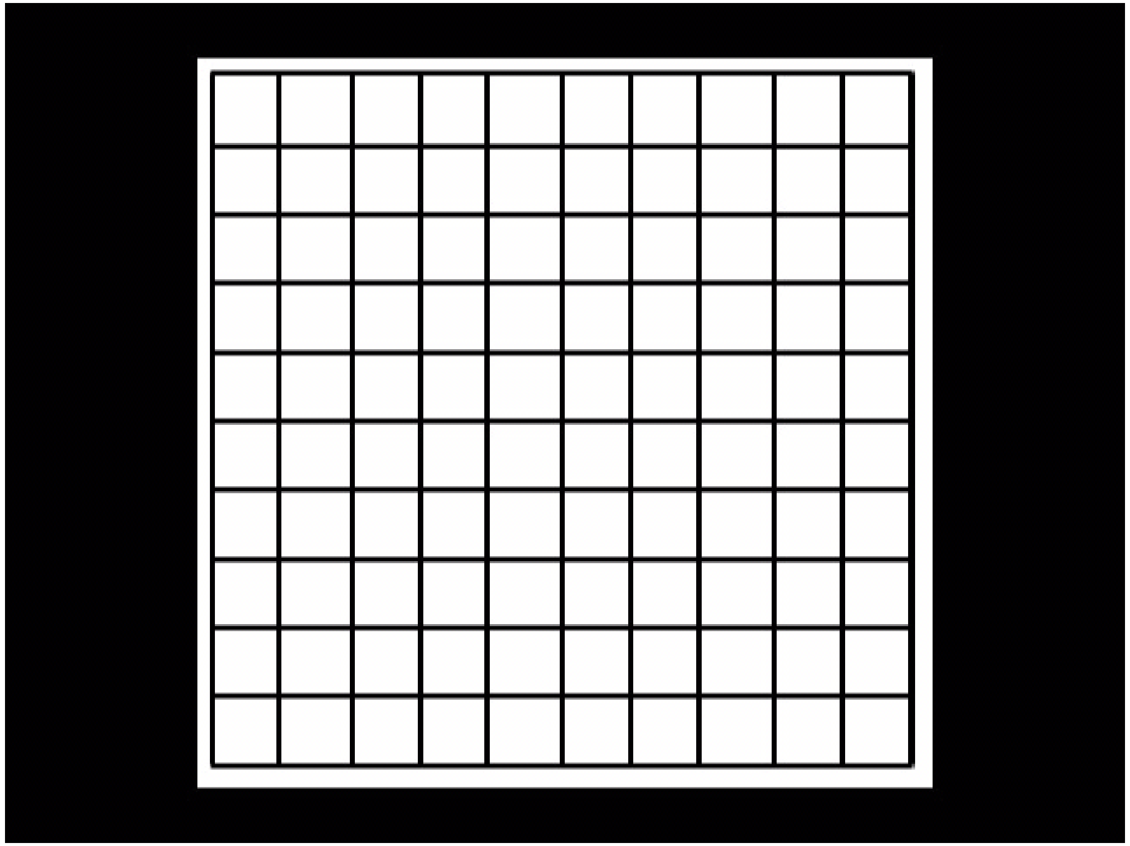


Extraction of Connected Components

- This algorithm extracts a component by selecting a point on a binary object A
- Works similar to region filling, but this time we use in the conjunction the object A, instead of it's complement

Extraction of Connected Components

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



The End