Image Morphology

Partially adopted from Brian Mac Namee

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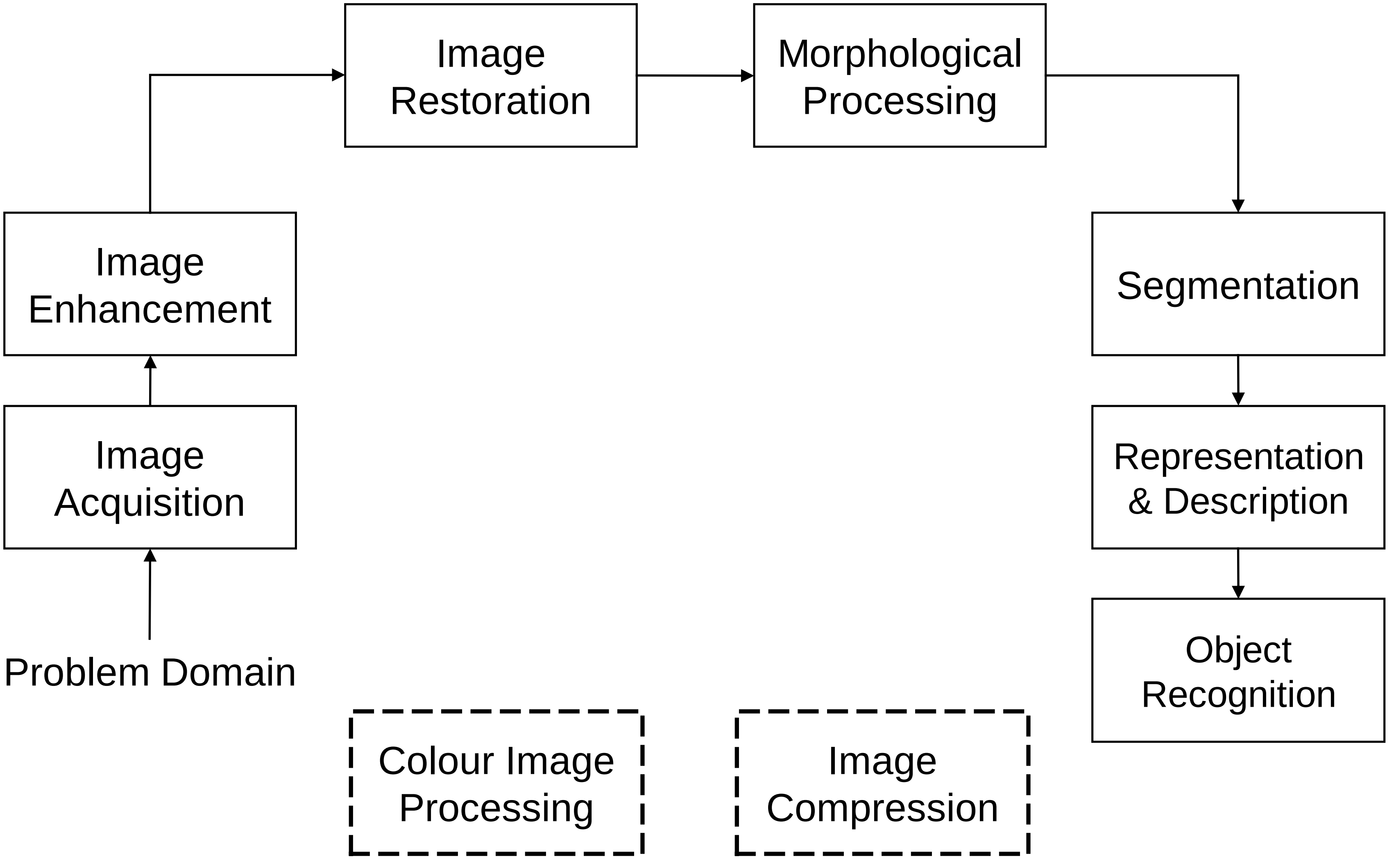
Phases of Digital Image Processing



Phases of Digital Image Processing : Morphological Processing

Image Restoration

Morphological Processing

Image Enhancement

Segmentation

Image Acquisition

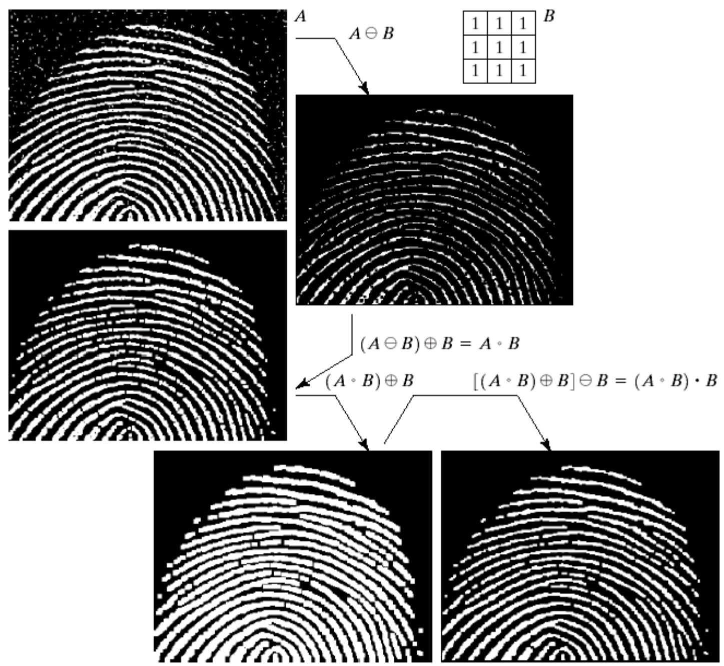
Representation & Description

Problem Domain

Object Recognition

Colour Image Processing

Image Compression



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What is Morphology?

Morphological image processing (or *morphology*) describes a range of image processing techniques that deal with the shape (or morphology) of features in an image.

Morphological operations are typically applied to remove imperfections introduced during segmentation, and so typically operate on bi-level images.

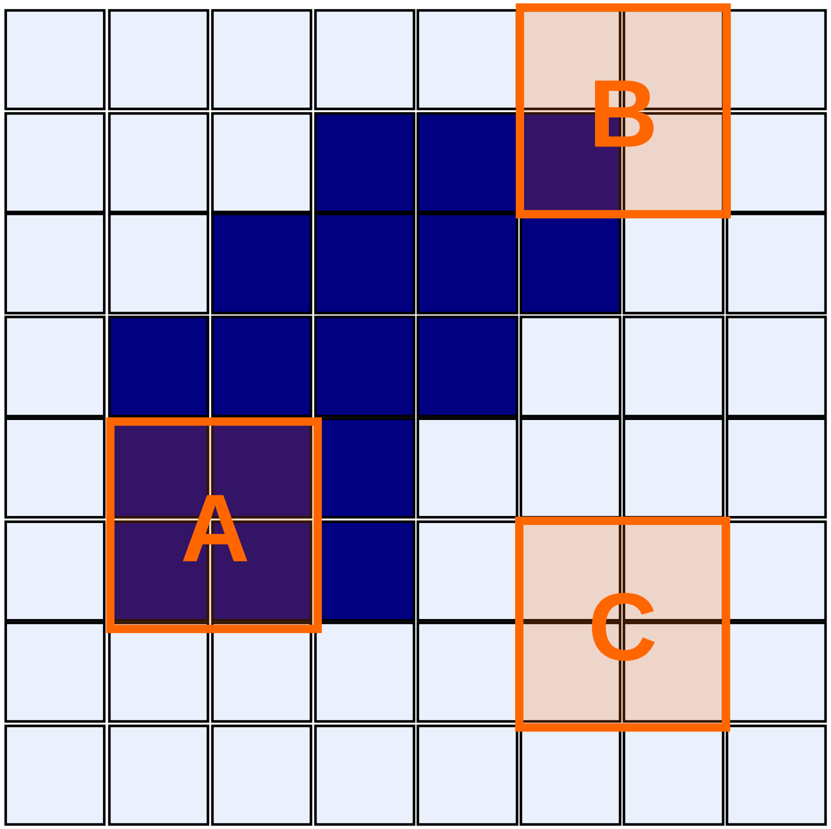
Example

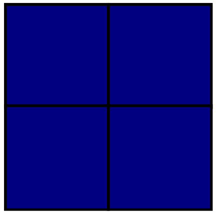
Image after segmentation

Image after segmentation and morphological processing

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

Structuring elements can be any size and make any shape.

For simplicity we use rectangular structuring elements with their origin at the middle pixel.

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

Fitting & Hitting

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0
0	0	1	**B** 1	1	1	1	0	**C** 0	0	0	0
0	1	1	1	1	1	1	1	0	0	0	0
0	1	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	1	0	0	0
0	0	1	1	1	1	1	**A** 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

1	1	1
1	1	1
1	1	1

Structuring Element 1

0	1	0
1	1	1
0	1	0

Structuring Element 2

Fitting & Hitting

Image Region	Structuring Element 1		Structuring Element 2	
	Fit	**Hit**	**Fit**	**Hit**
A	YES	YES	YES	YES
B	NO	YES	YES	YES
C	NO	YES	NO	NO

Fundamental Operations

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: <u>erosion</u> and <u>dilation</u>.

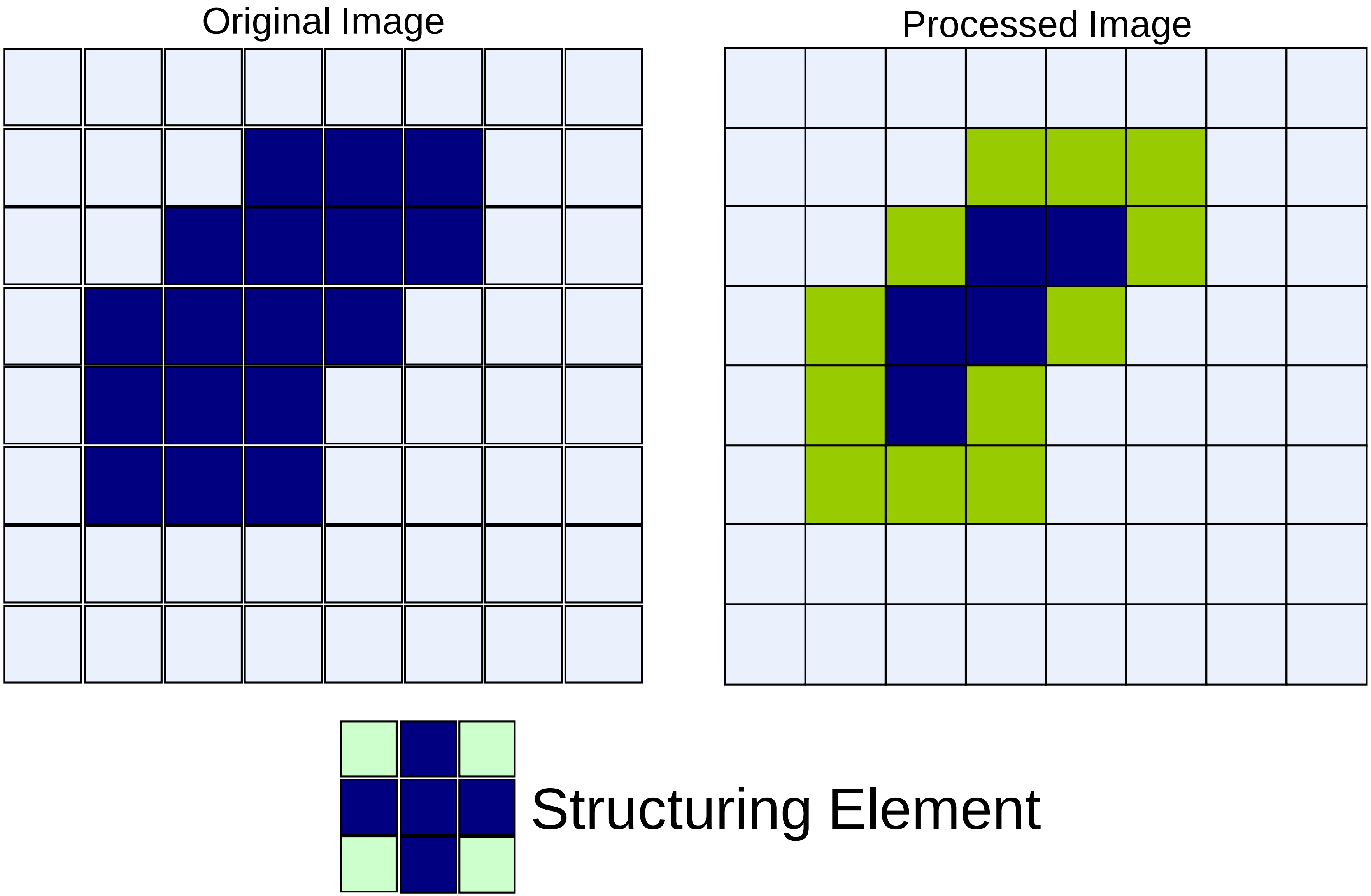
Erosion

Erosion of image *f* by structuring element *s* is given by $f \ominus s$.

The structuring element *s* is positioned with its origin at *(r, c)* and the new pixel value is determined using the rule:

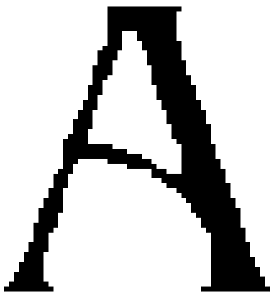
$$g(r,c) = \begin{cases} 1 & \text{if } s \text{ fits } f \\ 0 & \text{otherwise} \end{cases}$$

Erosion Example



Erosion Example 1

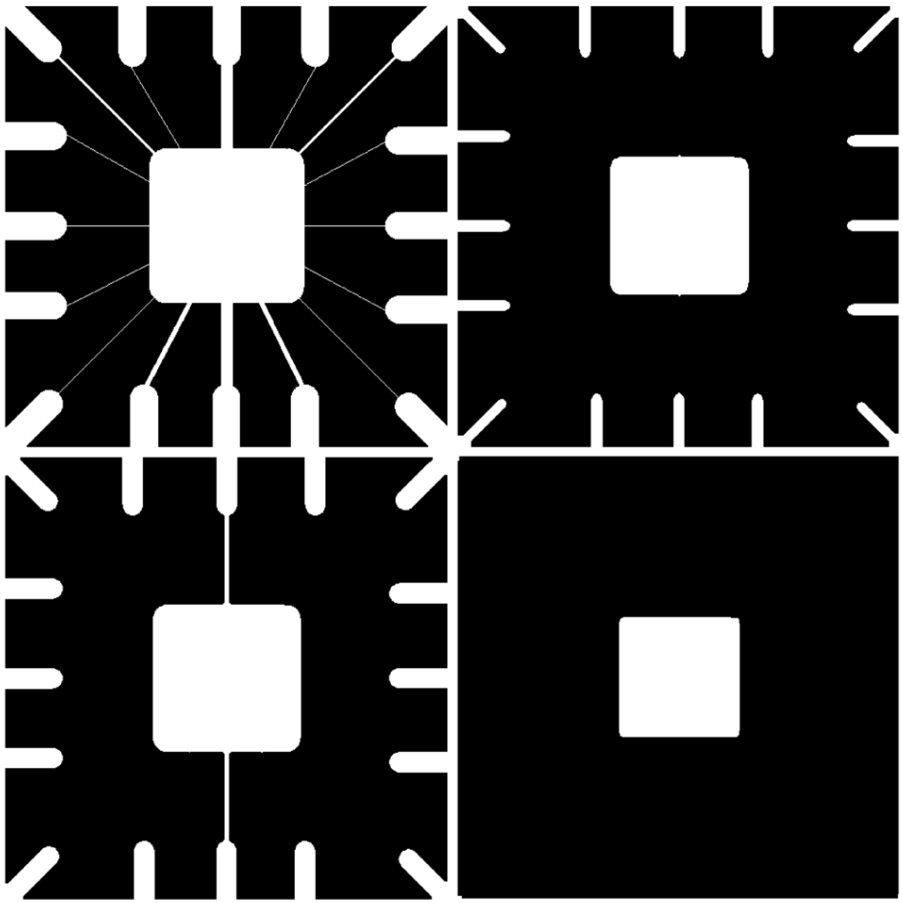
Original image



Erosion by 3*3 square structuring element

Erosion by 5*5 square structuring element

Erosion Example 2



Original image

After erosion with a disc of radius 10

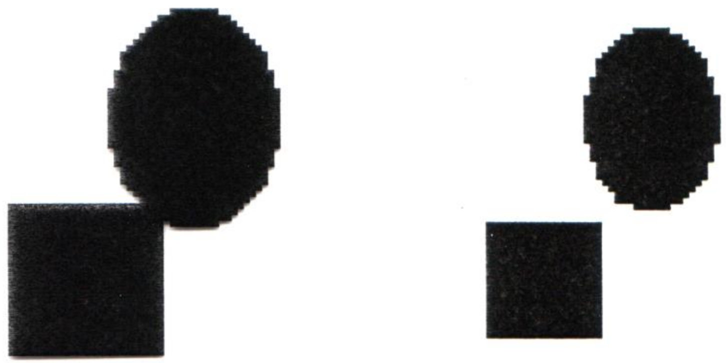
After erosion with a disc of radius 5

After erosion with a disc of radius 20

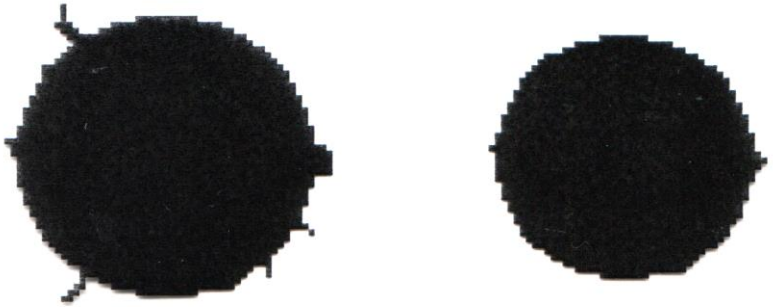
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Use of Erosion

Erosion can split apart joined objects



Erosion shrinks objects



Dilation

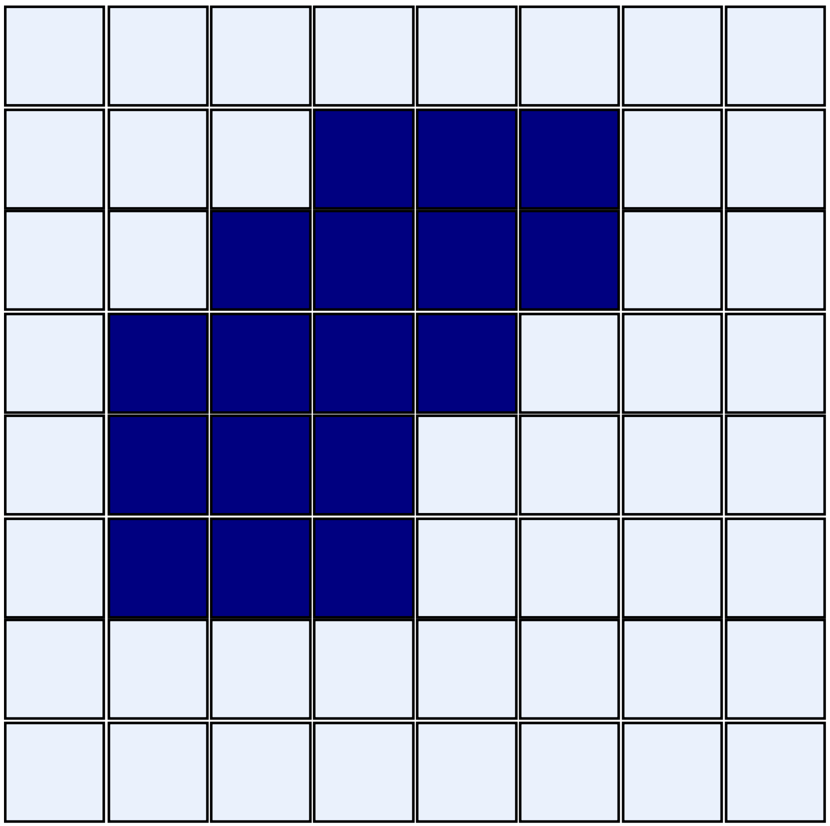
Dilation of image *f* by structuring element *s* is given by $f \oplus s$.

The structuring element s is positioned with its origin at *(r, c)* and the new pixel value is determined using the rule:

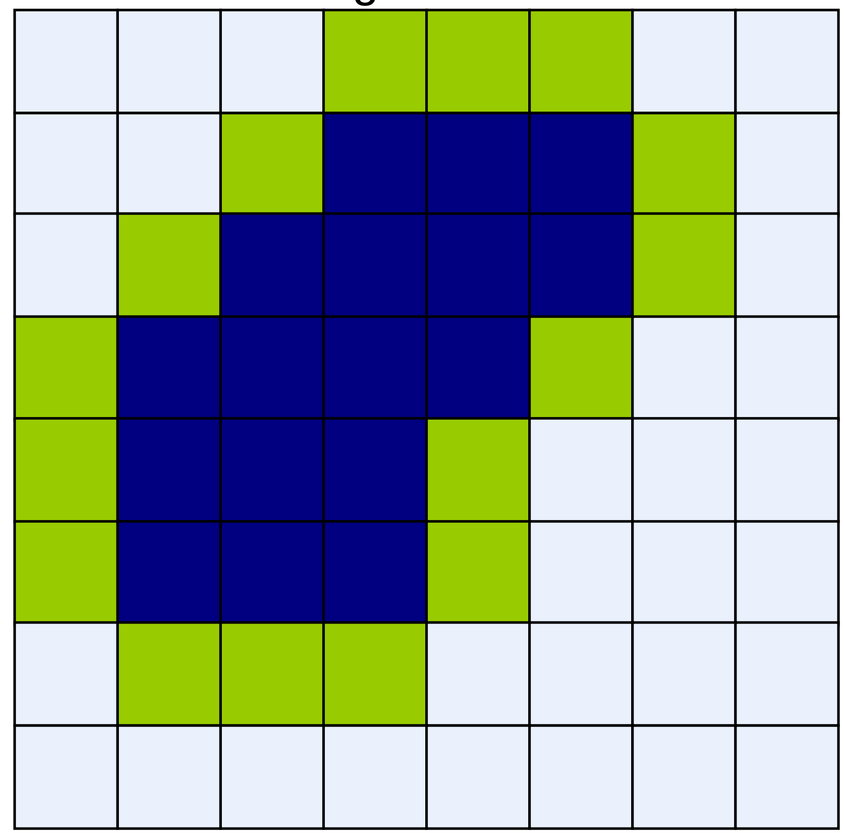
$$g(r,c) = \begin{cases} 1 & \text{if } s \text{ hits } f \\ 0 & \text{otherwise} \end{cases}$$

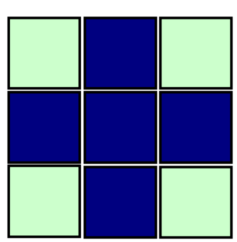
Dilation Example

Original Image



Processed Image With Dilated Pixels





Structuring Element

Dilation Example 1

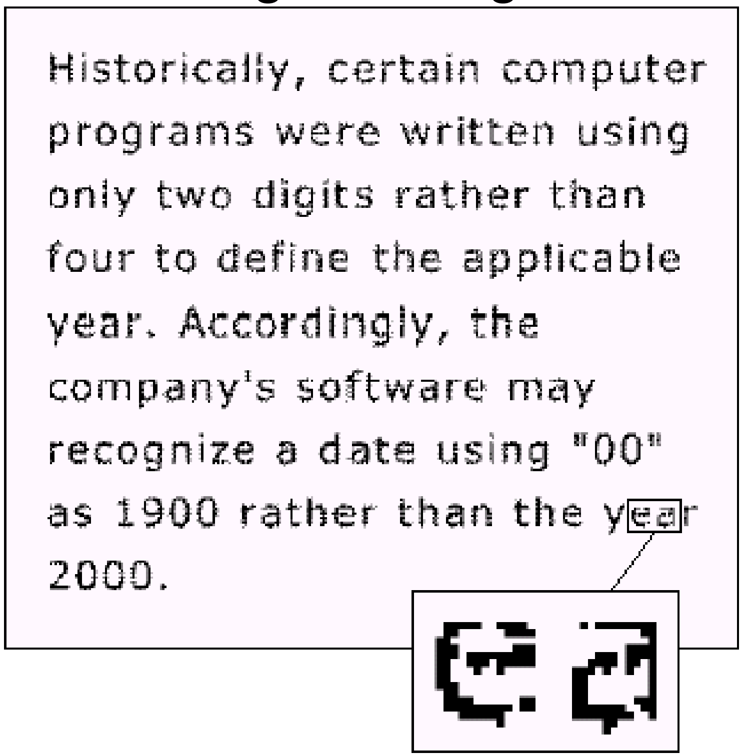
Original image

Dilation by 3*3 square structuring element

Dilation by 5*5 square structuring element

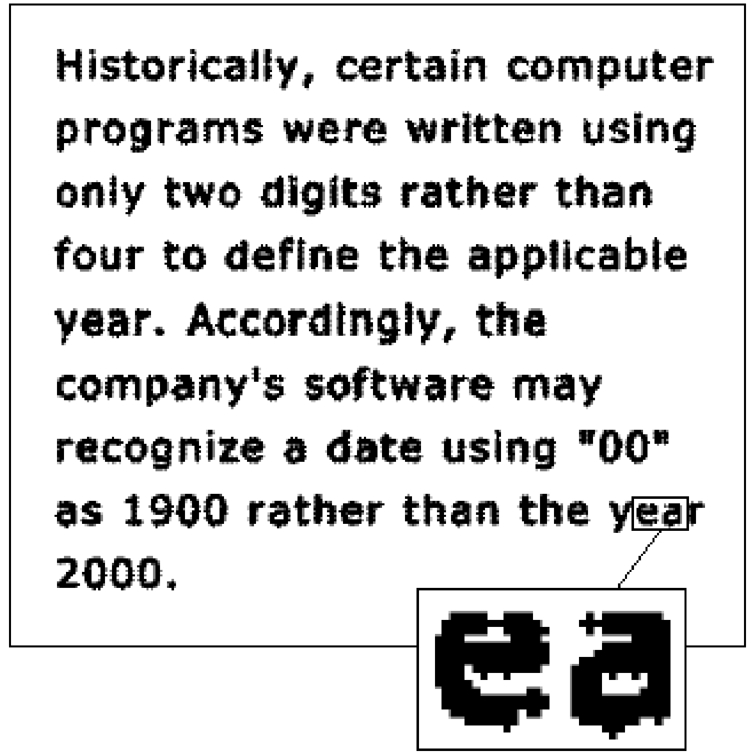
Dilation Example 2

Original image



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.

After dilation



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.

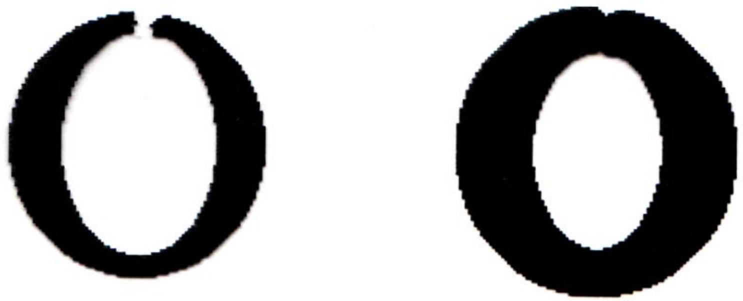
0	1	0
1	1	1
0	1	0

Structuring element

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Use of Dilation

Dilation can repair breaks



Dilation enlarges objects

Compound Operations

More effective morphological operations can be performed by <u>performing combinations of erosions and dilations.</u>

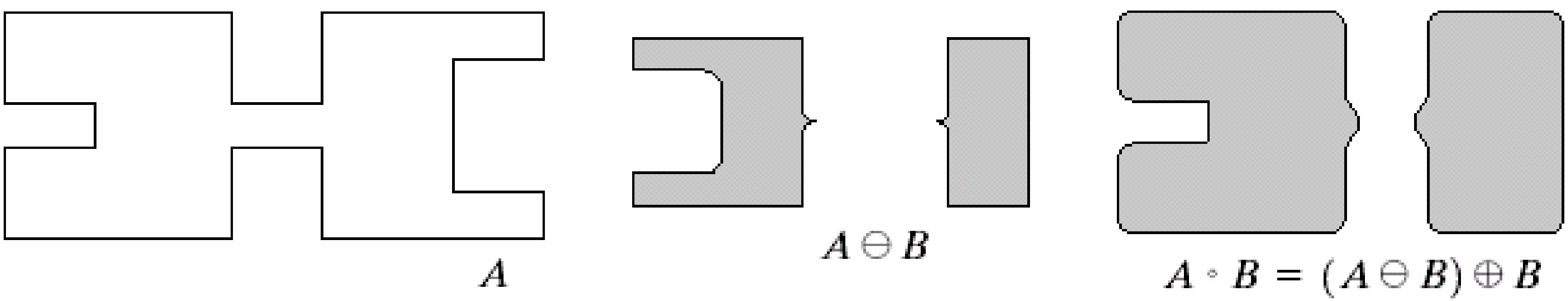
The most widely used of these *compound operations* are:

- Opening
- Closing

Opening

The opening of image *f* by structuring element *s*, denoted $f \circ s$ is simply an <u>erosion followed by a dilation.</u>

$$f \circ s = (f \ominus s) \oplus s$$



Original shape | After erosion | After dilation (opening)

A disc shaped structuring element is used.

Opening Example

Original Image

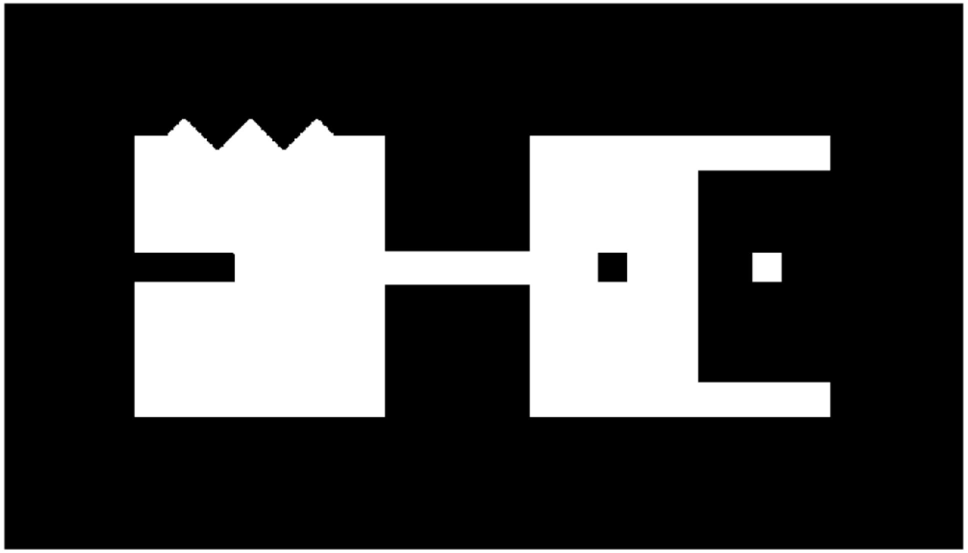
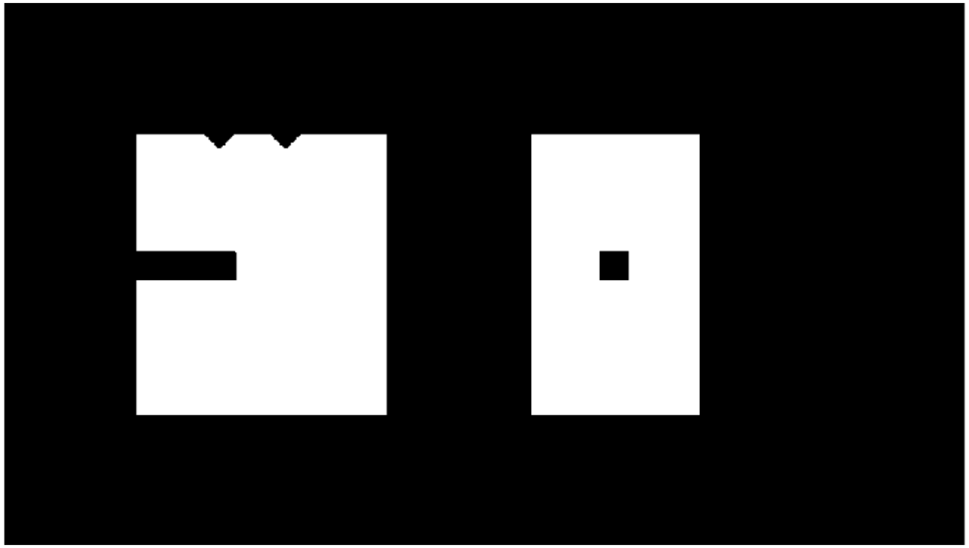
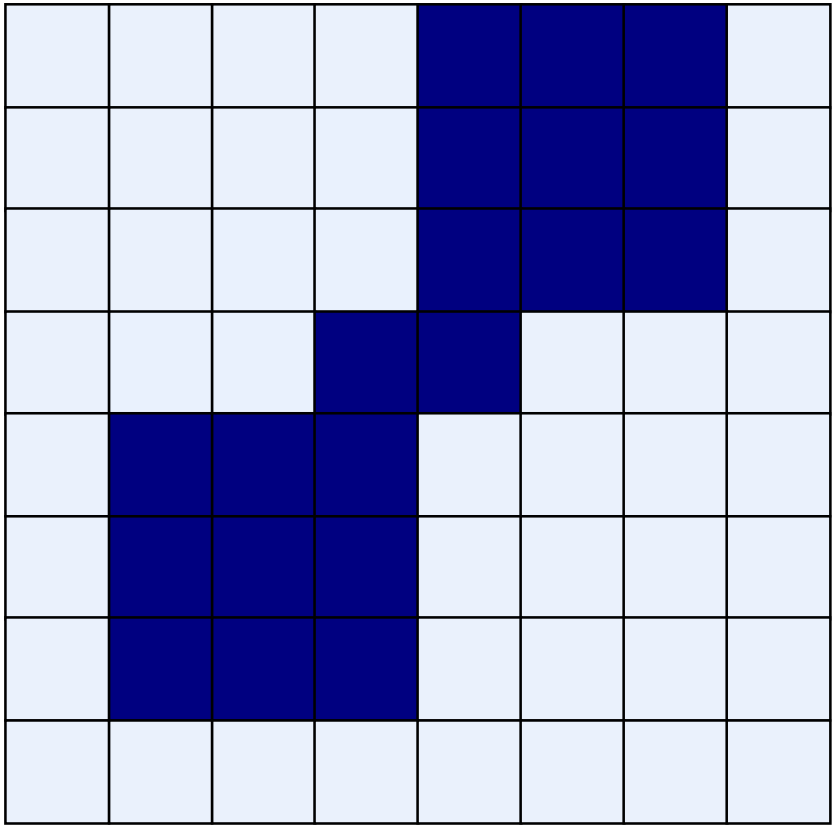


Image After Opening

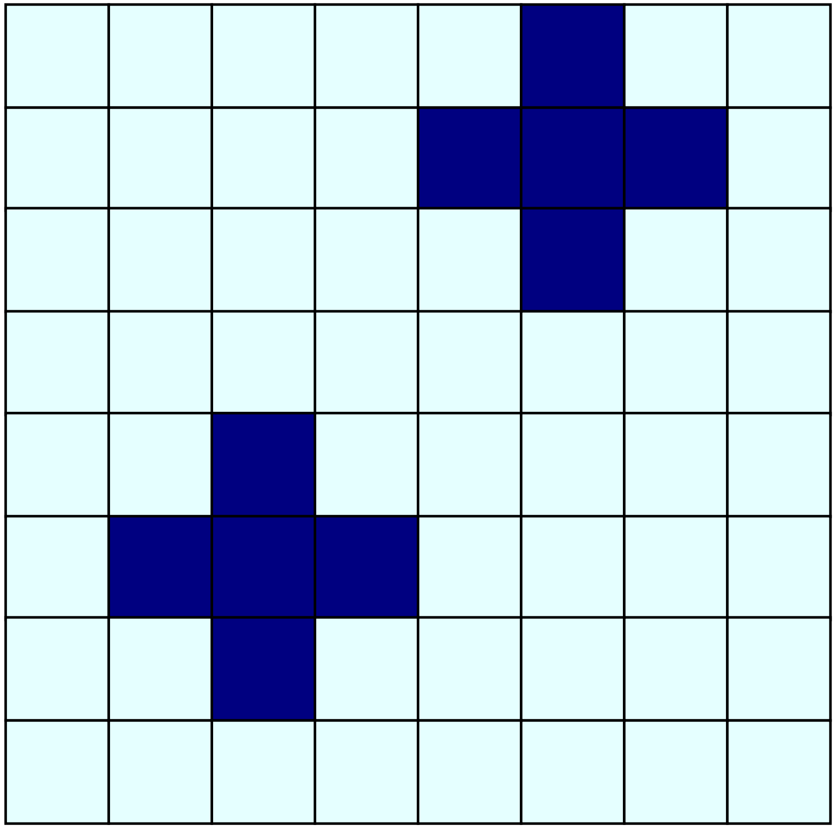


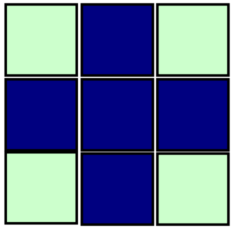
Opening Example

Original Image



Processed Image



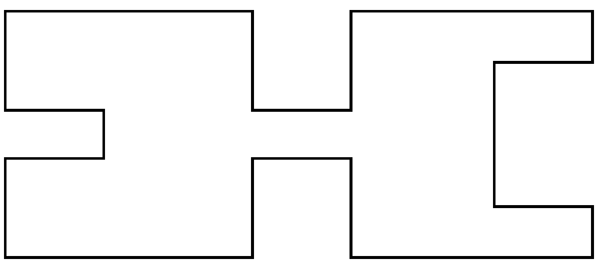


Structuring Element

Closing

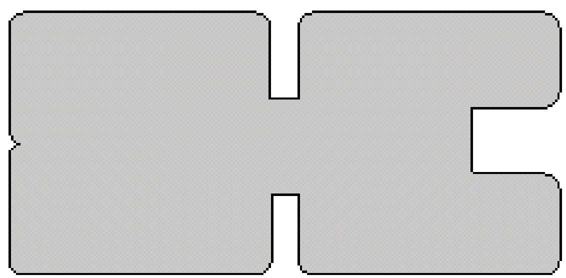
The closing of image *f* by structuring element *s*, denoted $f \bullet s$ is simply a dilation followed by an erosion.

$$f \bullet s = (f \oplus s) \ominus s$$



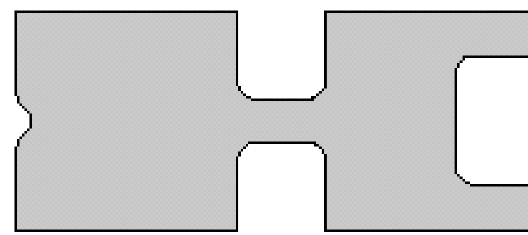
A

Original shape



$A \oplus B$

After dilation



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

After erosion (closing)

A disc shaped structuring element is used.

Closing Example

Original Image

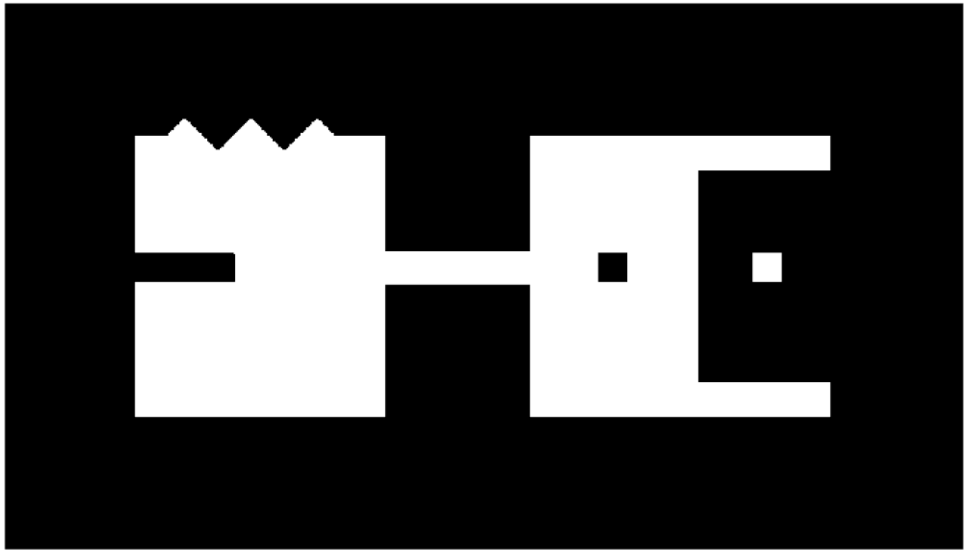
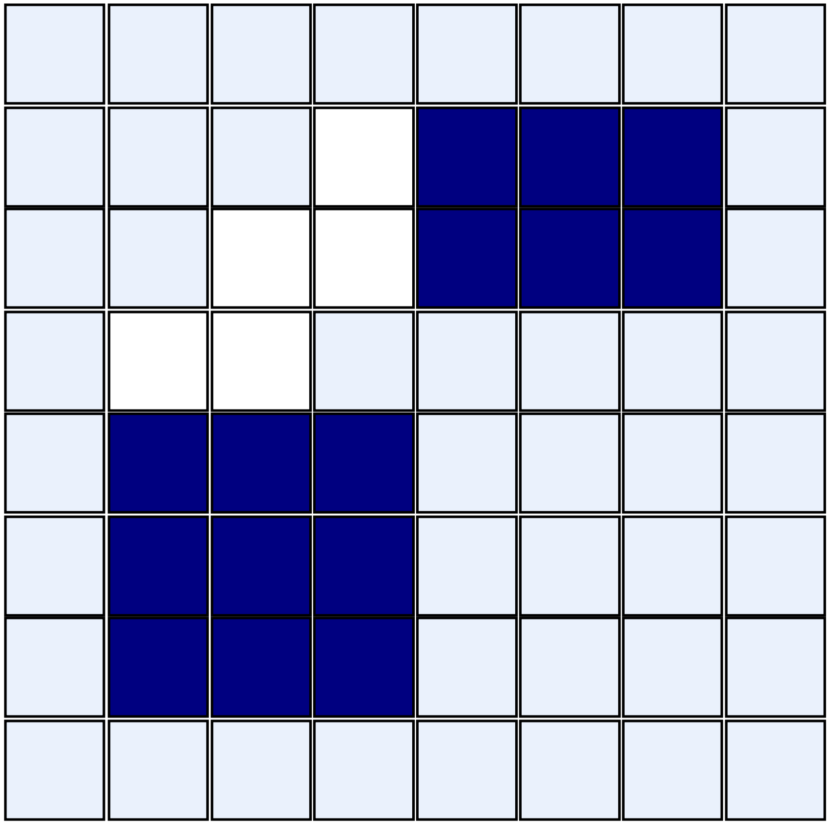


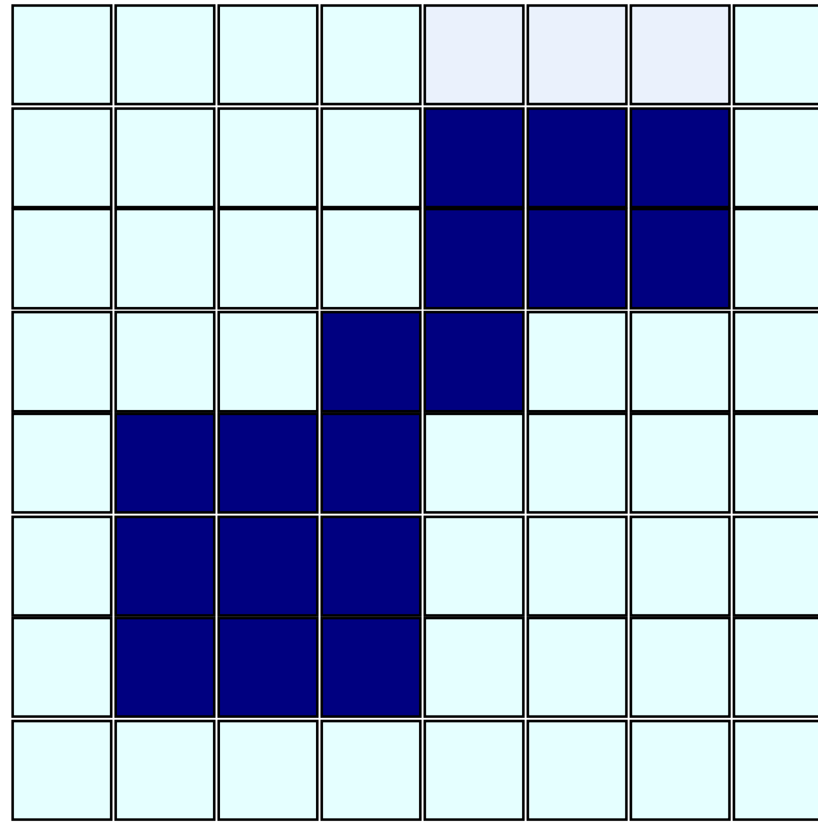
Image After Closing

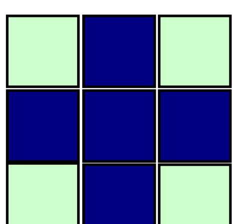
Closing Example

Original Image



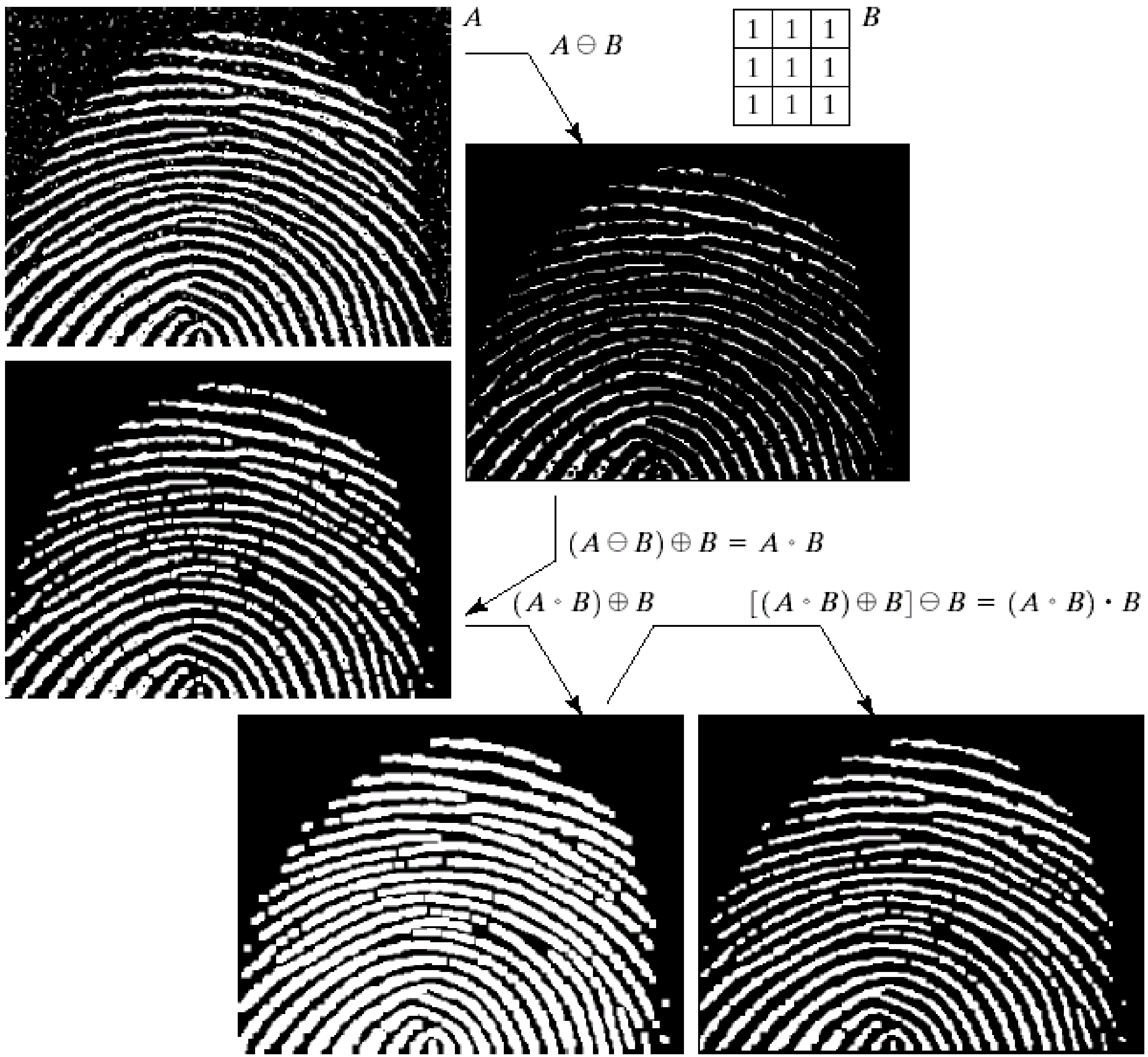
Processed Image





Structuring Element

Morphological Processing Example



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Morphological Algorithms

Using these simple technique we can perform some more interesting morphological algorithms.

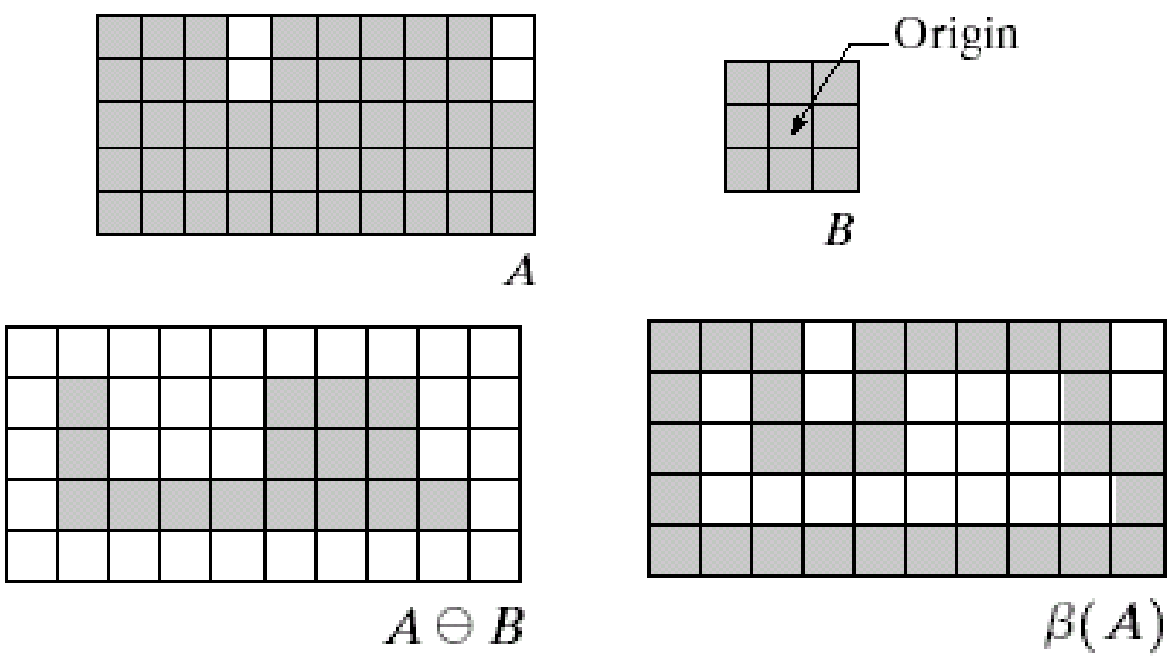
- Boundary extraction
- Region filling
- Extraction of connected components
- Thinning/Skeletonization

Boundary Extraction Algorithm

Extracting the boundary (or outline) of an object is often extremely useful.

The boundary can be given simply as

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



Boundary Extraction Example

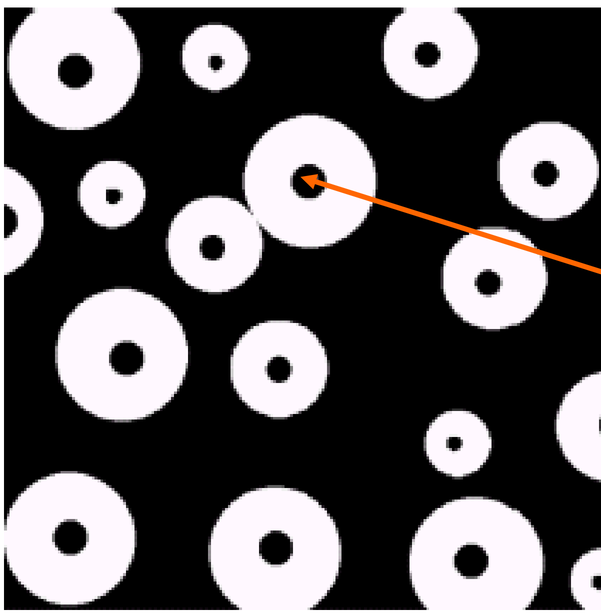
A simple image and the result of performing boundary extraction using a square 3x3 structuring element.

Original Image

Extracted Boundary

Region Filling

Given a pixel inside a boundary, region filling attempts to fill that boundary with object pixels.



Given a point inside here, can we fill the whole circle?

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Region Filling Algorithm

1. The key equation for region filling is

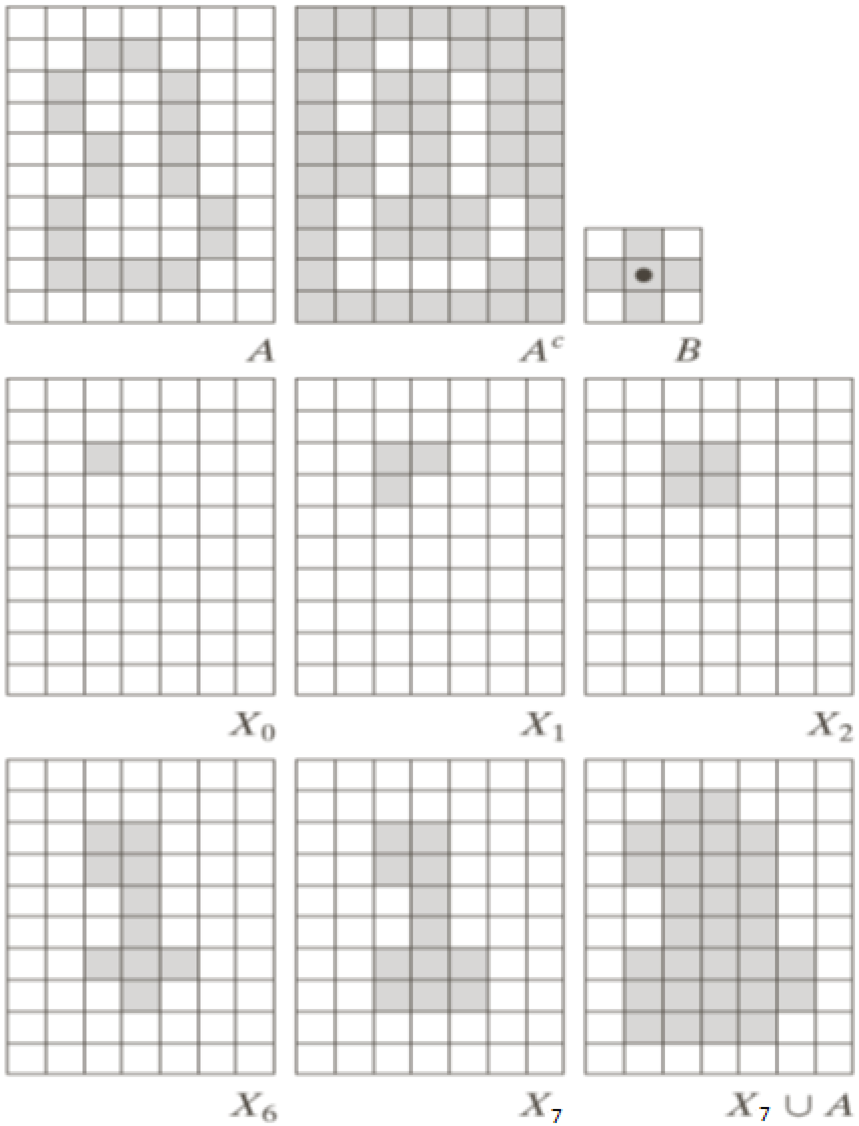
$$X_k = (X_{k-1} \oplus B) \cap A^c \qquad k = 1,2,3.....$$

Where X_0 is simply the starting point inside the boundary, B is a simple structuring element and A^c is the complement of A.

2. This equation is applied repeatedly until X_k is equal to X_{k-1}.

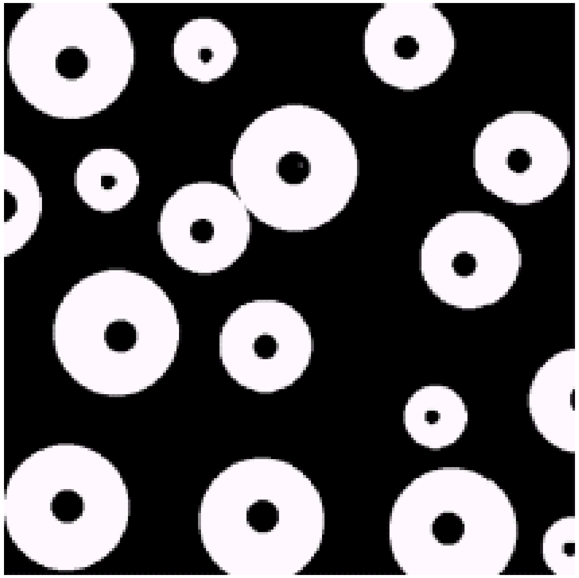
3. Finally the result is unioned with the original boundary.

Region Filling Step By Step

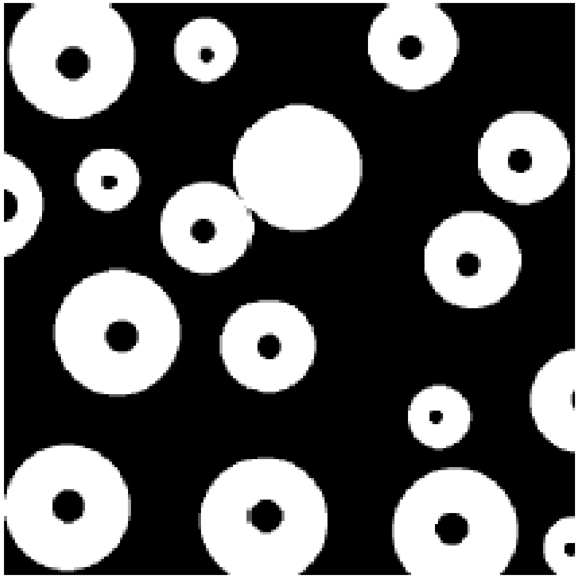


Region Filling Example

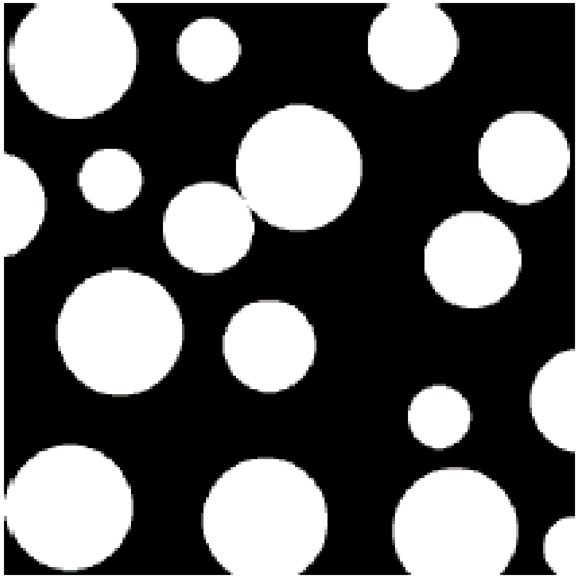
Images taken from Gonzalez & Woods, Digital Image Processing (2002)



Original Image



One Region Filled



All Regions Filled

Extraction of Connected Component Algorithm

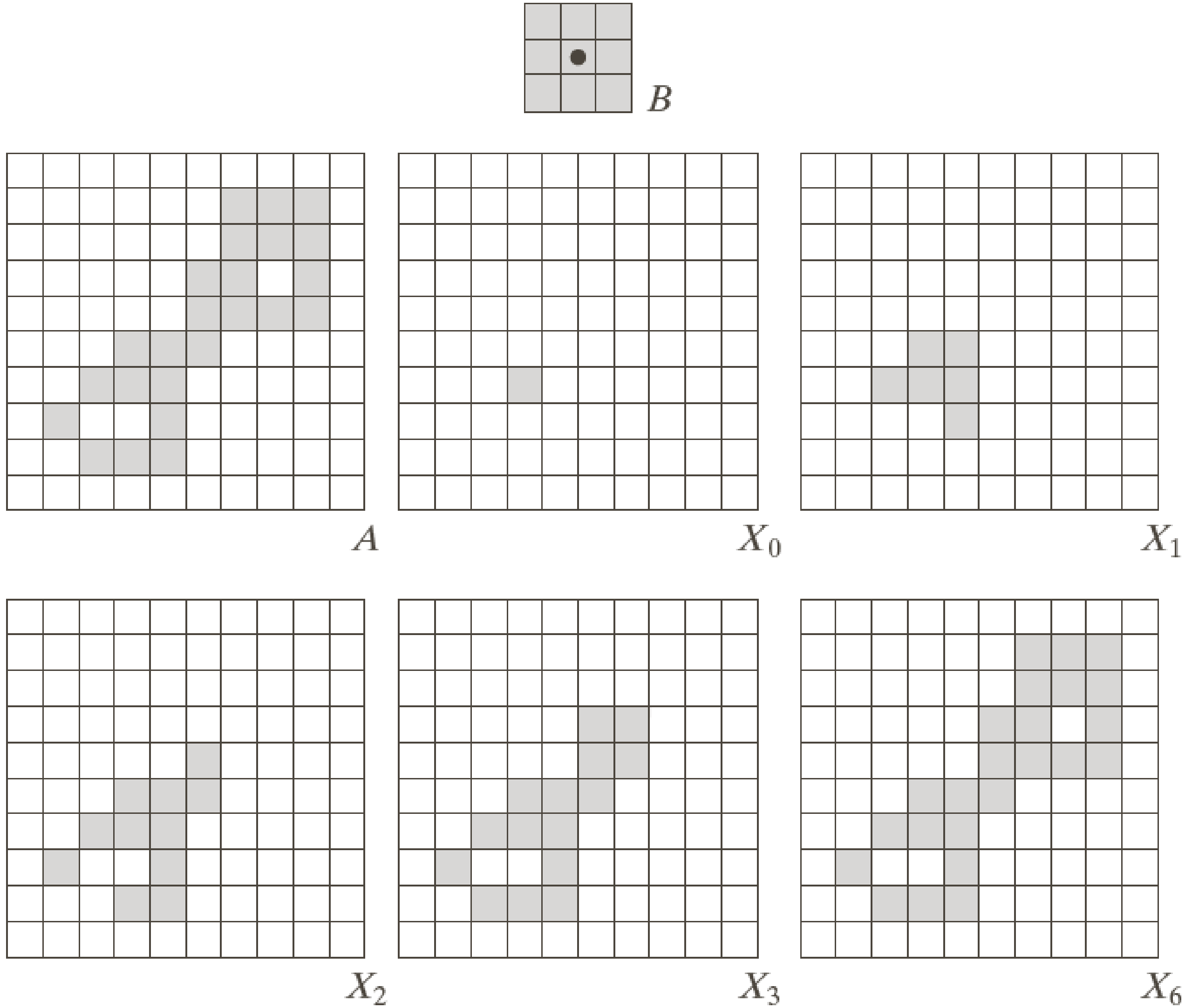
1. The key equation for connected component extraction is

$$X_k = (X_{k-1} \oplus B) \cap A \qquad k = 1, 2, 3.....$$

Where X_0 is simply the starting point of the connected component which is known to us beforehand and B is a simple structuring element.

2. This equation is applied repeatedly until X_k is equal to X_{k-1}.

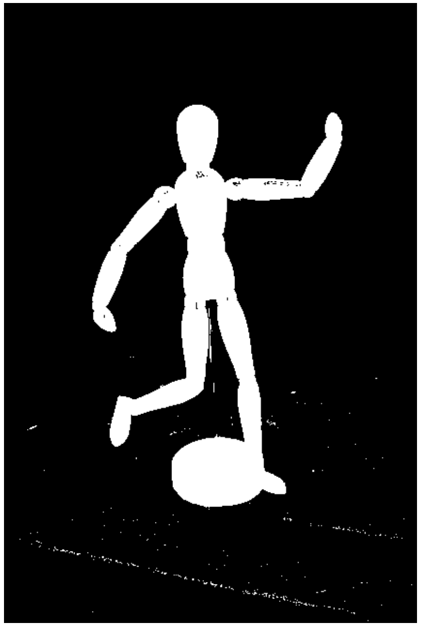
Extraction of Connected Component Step By Step



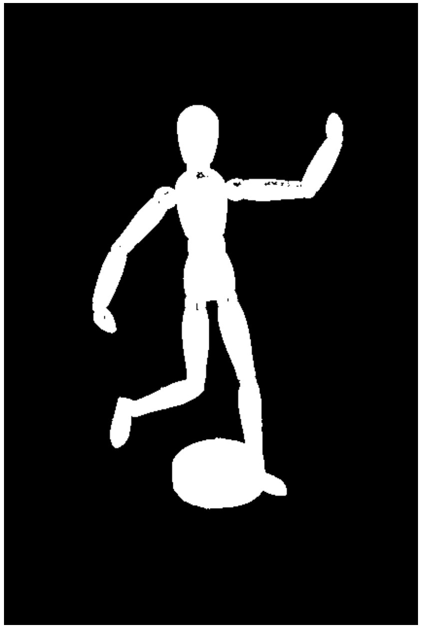
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Improving Segmentation Outcome

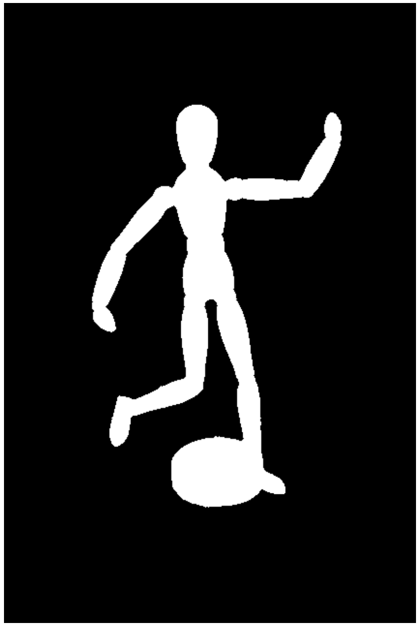
Original Image



Initial thresholding



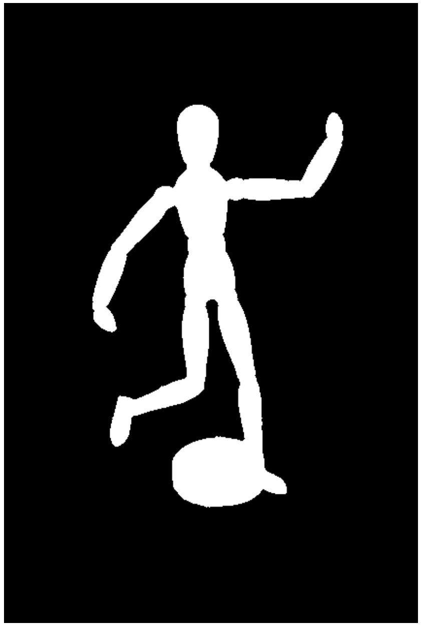
After Opening



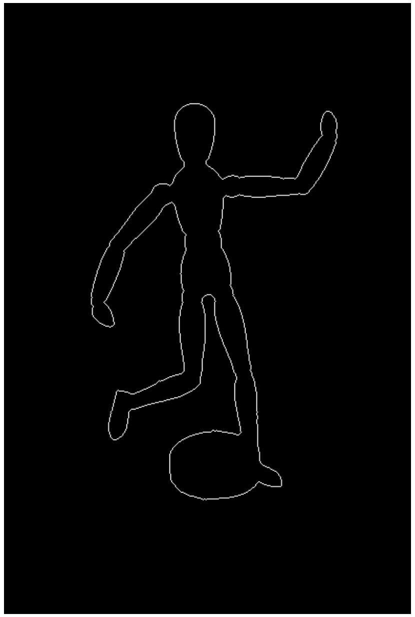
After Closing

Thinning / Skeletonization Example

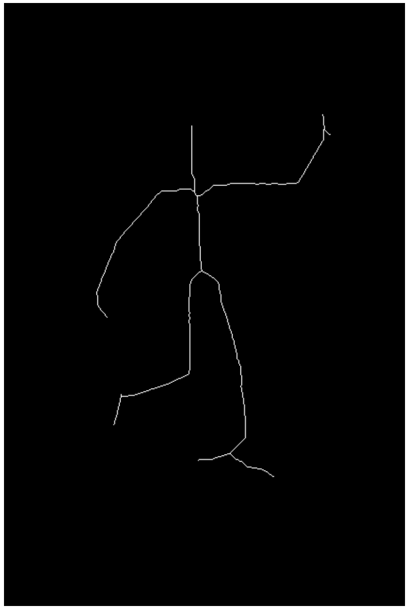
Original Image



Segmented Image



Boundary Extraction



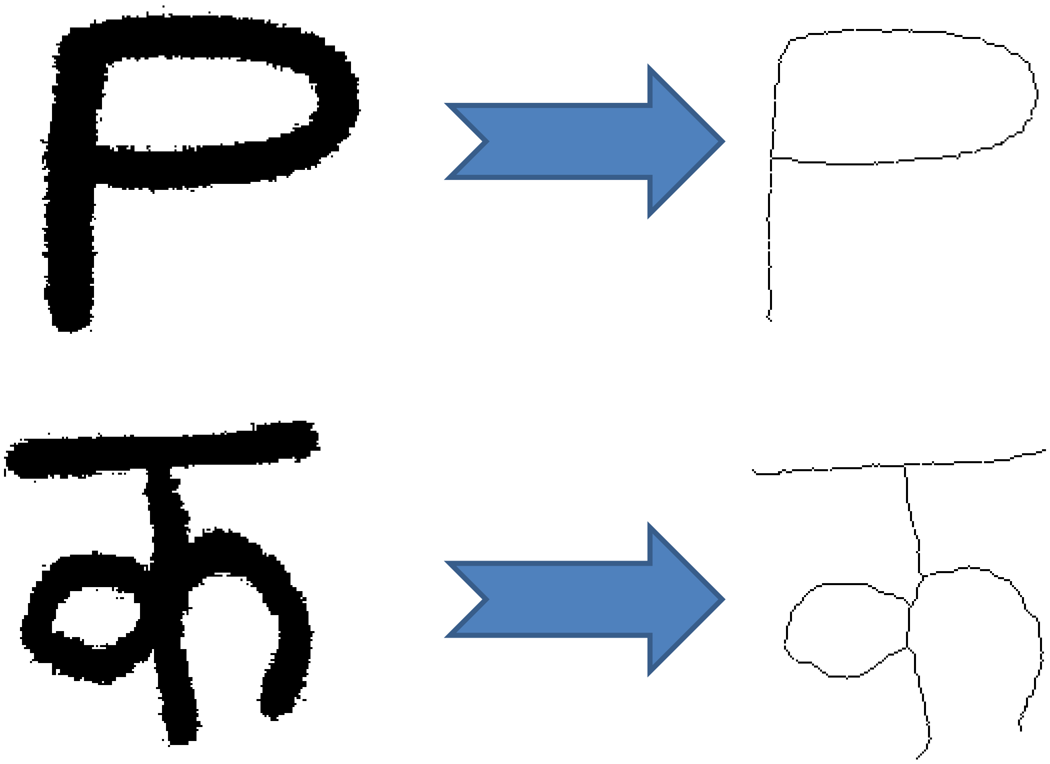
Thinned Image

Thinning

Generates single pixel wide skeletons of the input images.

It has wide applications in shape analysis and classification.

Thinning / Skeletonization Example



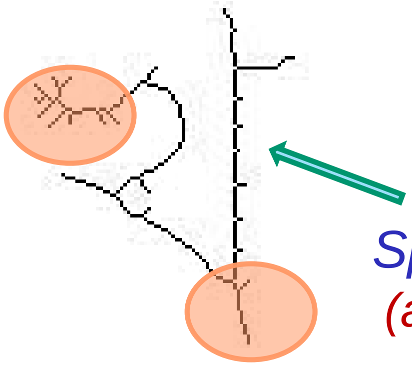
Original Image

Repeatedly run until 1-pixel thick

Challenges in Thinning?

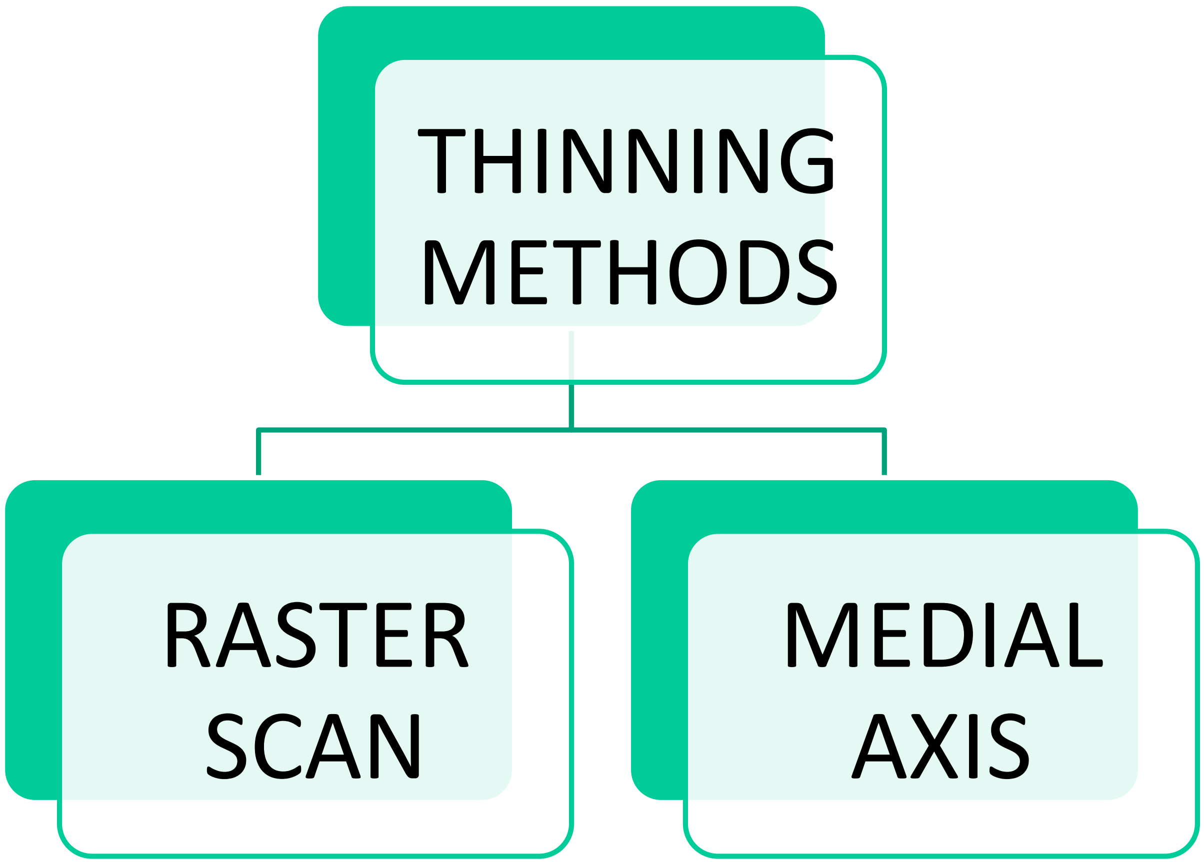
- Most of the thinning methods can not preserve the local features and true shapes of images at the junction point and end point.

Shape distortion at Junction and End Points (circle)



Spurious strokes (arrow)

Thinning Methods



Raster Scan Based Methods

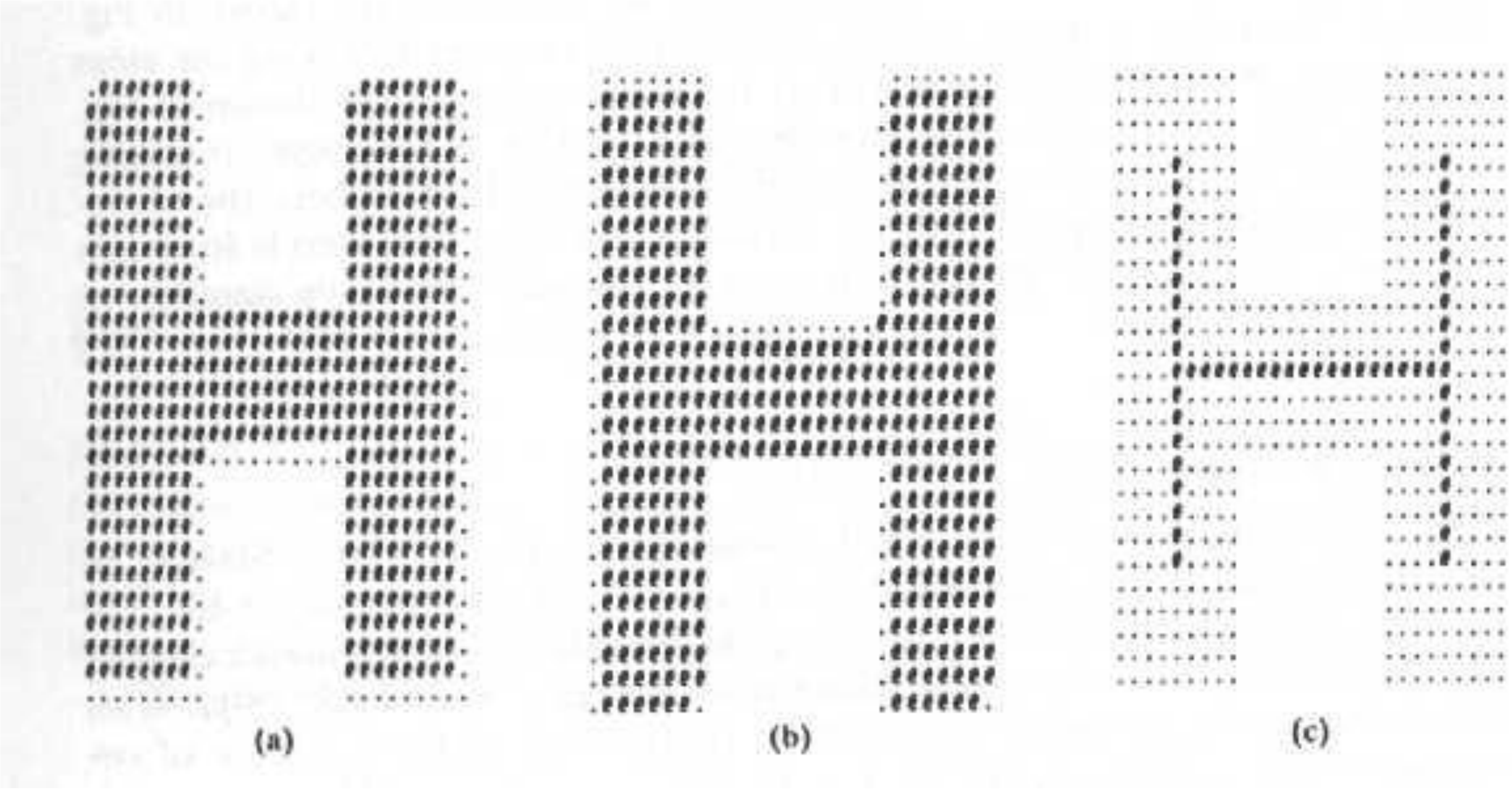
They are rule based methods.

Uses templates to eliminate pixels.

If the neighborhood of the pixel matches the mask/template then the pixel is removed.

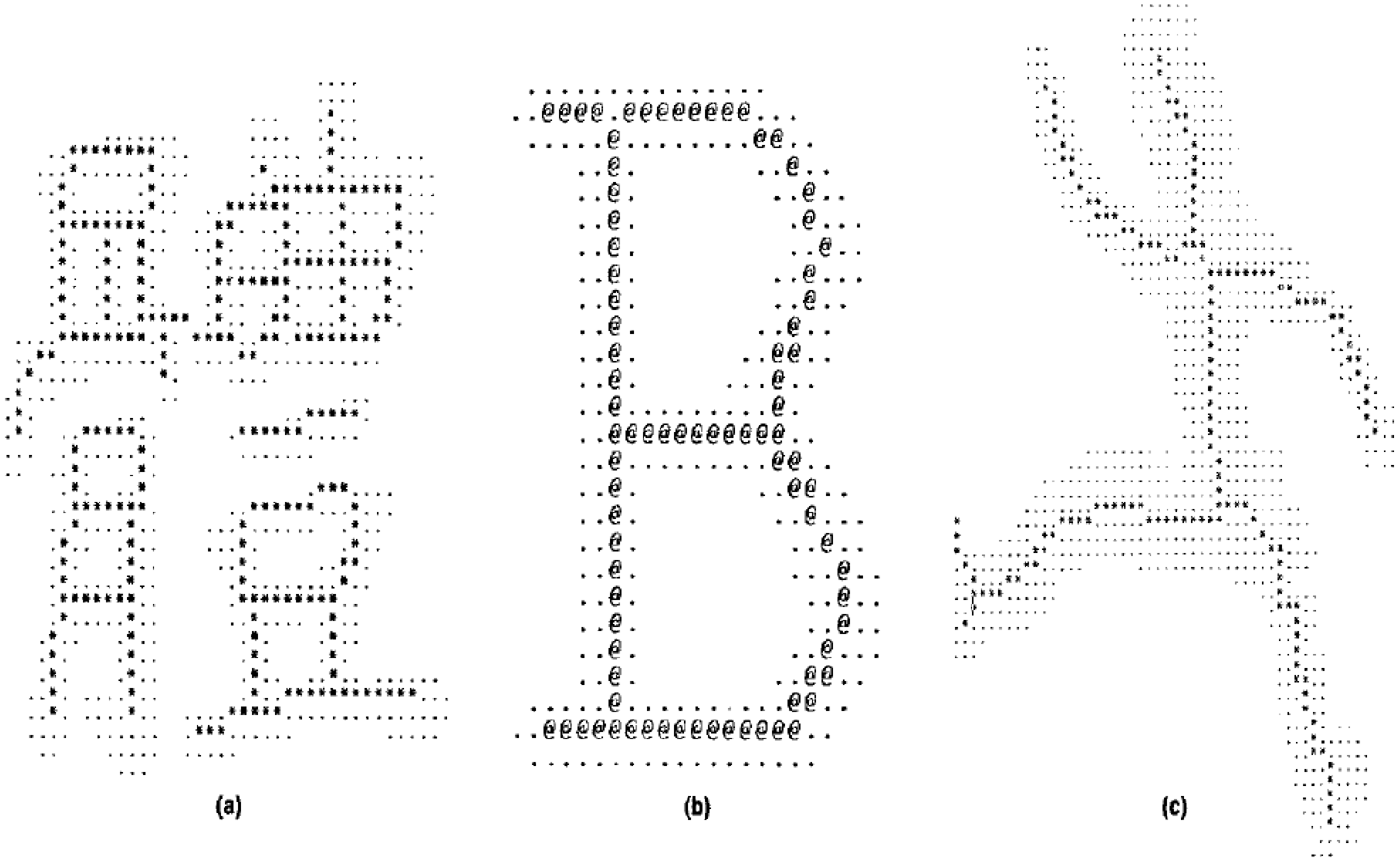
This mask is run over the entire image and the process is repeated for each pixel in the image.

Raster Scan Based Thinning / Skeletonization Example



T.Y. Zhang, C.Y. Suen, *A fast parallel algorithm for thinning digital patterns*, Communications of the ACM, vol. 27, No. 3, pp. 236-239, 1984.

Raster Scan Based Thinning / Skeletonization Example



(a) (b) (c)

T.Y. Zhang, C.Y. Suen, *A fast parallel algorithm for thinning digital patterns*, Communications of the ACM, vol. 27, No. 3, pp. 236-239, 1984.

Raster Scan Based Thinning / Skeletonization Example

1	1	0
0	1	0
0	1	1

0	1	0
1	1	0
0	0	1

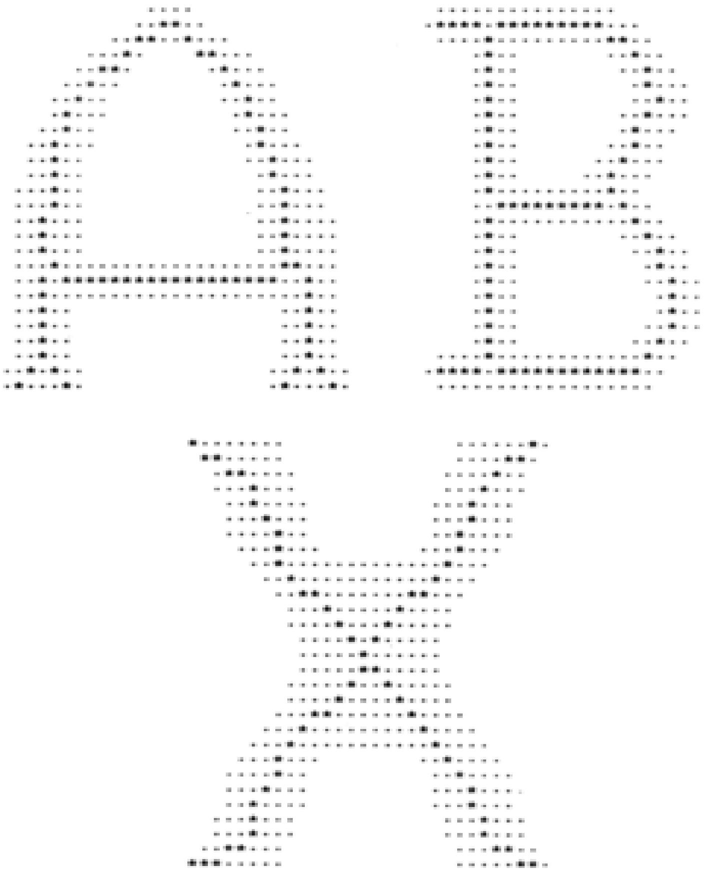
1	1	1
0	1	0
1	1	1

0	1	0
1	1	1
0	1	0

Templates for pixel preservation

A. Datta and S. K. Parui, *A robust parallel thinning algorithm for binary images*, Pattern Recognition, Elsevier, vol. 27, pp. 1181-1192, 1994.

Raster Scan Based Thinning / Skeletonization Example



A. Datta and S. K. Parui, *A robust parallel thinning algorithm for binary images*, Pattern Recognition, Elsevier, vol. 27, pp. 1181-1192, 1994.

Medial Axis based Methods

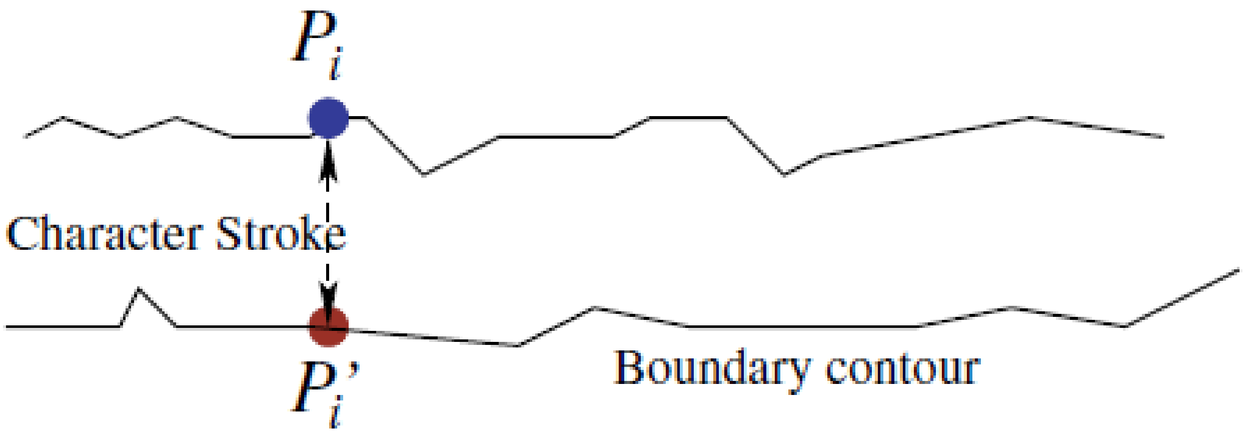
They generate medial points in between two parallel contour segments.

This process is repeated for all parallel contour segments.

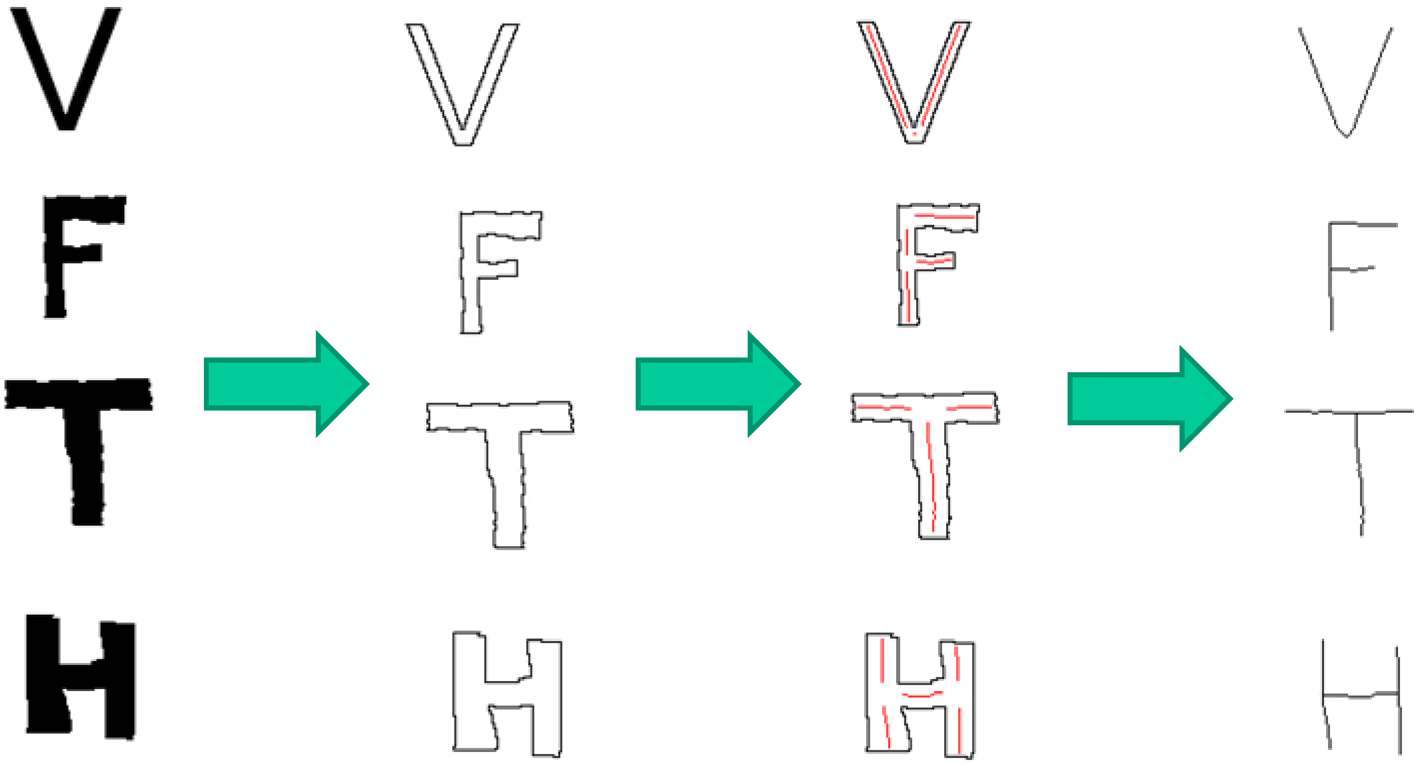
Interpolation may be used to reconstruct the junction regions.

Medial-axis Based Methods

Medial Axis Generation



Medial-axis Based Thinning / Skeletonization Example



Mathematical Example

Problem : Consider a binary image **S,** which is the result of graylevel segmentation on image **I** as shown below. The object pixels in image **S** are labelled as '1'.

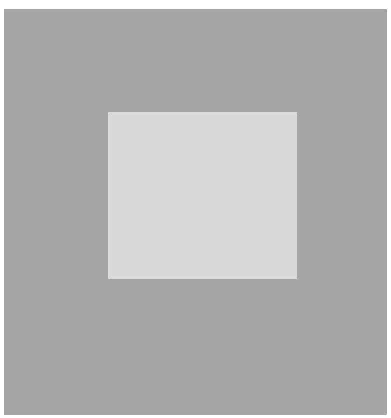
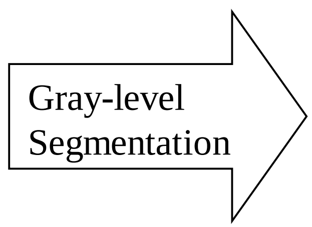


Image I



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

Image S

Mathematical Example

If you apply Labeling Algorithm on image **S**, how many objects will be detected ?

Answer: *Labeling algorithm - 5 objects*

How many object do you observe visually in image **I** ?

Answer: *Observe visually – 1 object*

How to solve this conflict?

Use *Opening* (*Erosion* followed by *Dilation*) to remove small objects treated as noise.

Summary

The purpose of morphological processing is primarily to remove imperfections added during segmentation.

The basic operations are *erosion* and *dilation.*

Using the basic operations we can perform *opening* and *closing.*

More advanced morphological operation can then be implemented using combinations of all of these.