Digital Image Processing

Morphological Image Processing

Course Website: http://www.comp.dit.ie/bmacnamee

Contents

Once segmentation is complete, morphological operations can be used to remove imperfections in the segmented image and provide information on the form and structure of the image

In this lecture we will consider

- What is morphology?
- Simple morphological operations
- Compound operations
- Morphological algorithms

1, 0, Black, White?

Throughout all of the following slides whether 0 and 1 refer to white or black is a little interchangeable

All of the discussion that follows assumes segmentation has already taken place and that images are made up of 0s for background pixels and 1s for object pixels

After this it doesn't matter if 0 is black, white, yellow, green…….

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

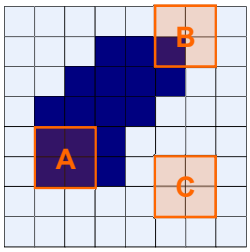
Quick Example

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

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Structuring Elements

Structuring elements can be any size and make any shape

However, for simplicity we will 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

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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	0	**C**	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	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

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Fundamental Operations

Fundamentally morphological image processing is very like 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: **erosion** and **dilation**

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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 (x, y) and the new pixel value is determined using the rule:

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

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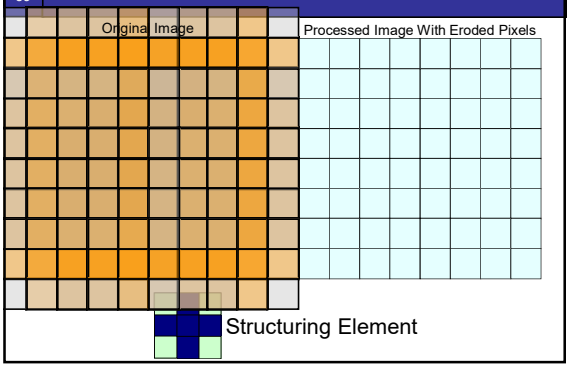
Erosion Example



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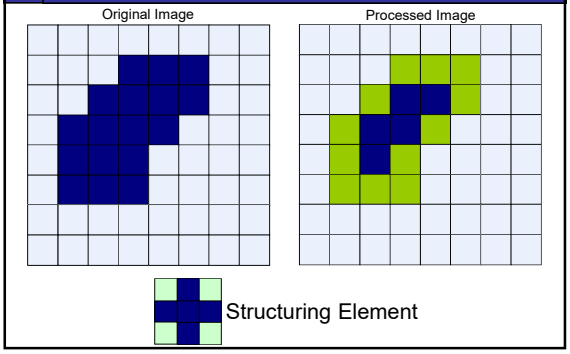
Erosion Example



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Erosion Example 1

Original image | Erosion by 3*3 square structuring element | Erosion by 5*5 square structuring element

Watch out: In these examples a 1 refers to a black pixel!

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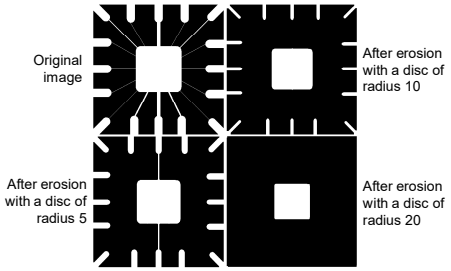
Erosion Example 2



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

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What Is Erosion For?

Erosion can split apart joined objects

Erosion can strip away extrusions

Watch out: Erosion shrinks objects

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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 (x, y) and the new pixel value is determined using the rule:

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

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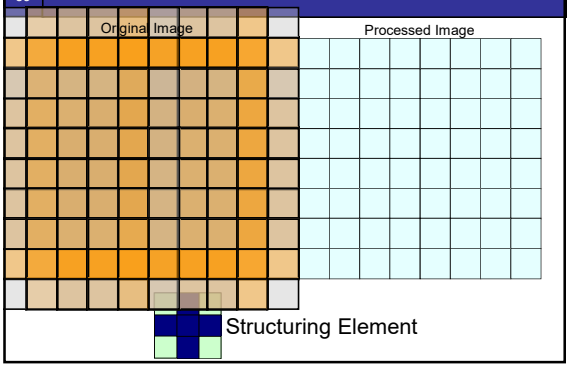
Dilation Example



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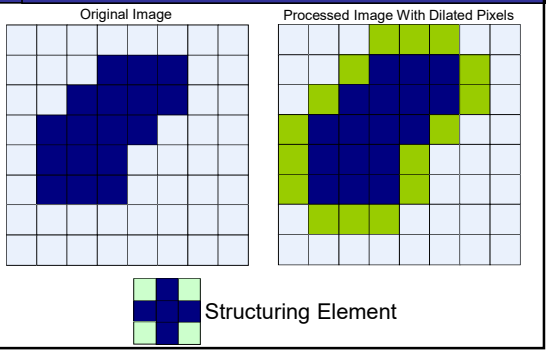
Dilation Example



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Dilation Example 1

Original image | Dilation by 3*3 square structuring element | Dilation by 5*5 square structuring element

Watch out: In these examples a 1 refers to a black pixel!

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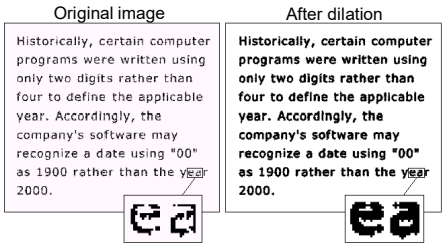
Dilation Example 2



Structuring element

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

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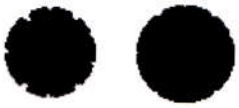
What Is Dilation For?

Dilation can repair breaks

Dilation can repair intrusions



Watch out: Dilation enlarges objects

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Compound Operations

More interesting morphological operations can be performed by performing combinations of erosions and dilations

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

- Opening
- Closing

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Opening

The opening of image f by structuring element s, denoted $f \circ s$ is simply an erosion followed by a dilation

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

Original shape | After erosion | After dilation (opening)

Note a disc shaped structuring element is used

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

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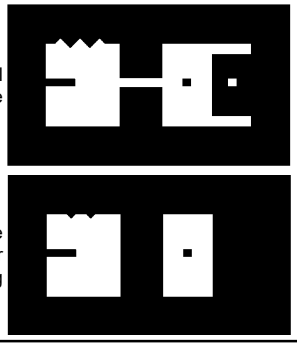
Opening Example



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

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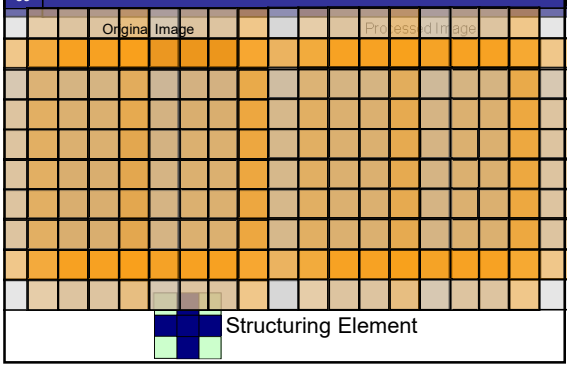
Opening Example



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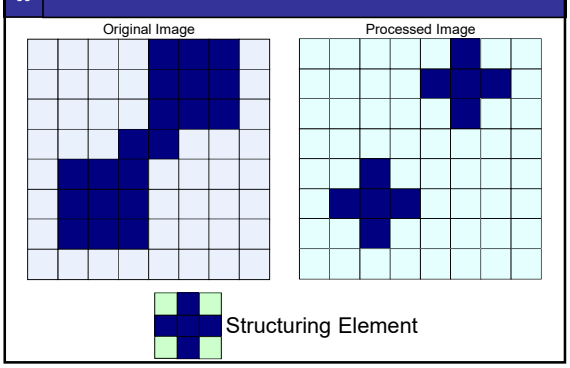
Opening Example



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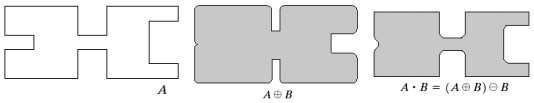
Closing

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

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



Note a disc shaped structuring element is used

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

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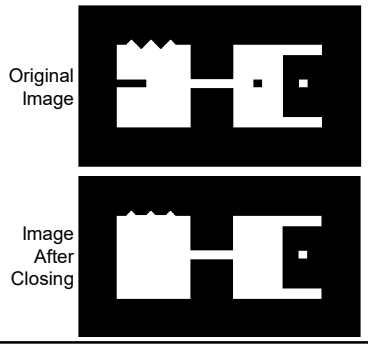
Closing Example



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

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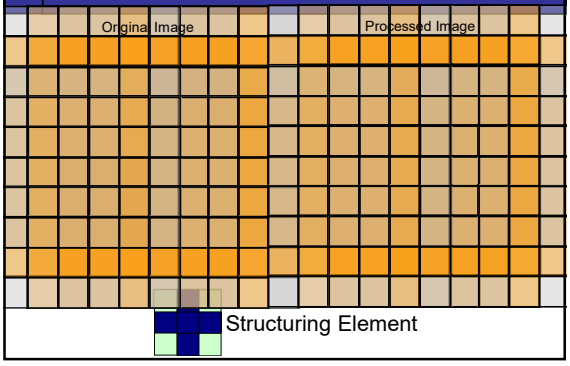
Closing Example



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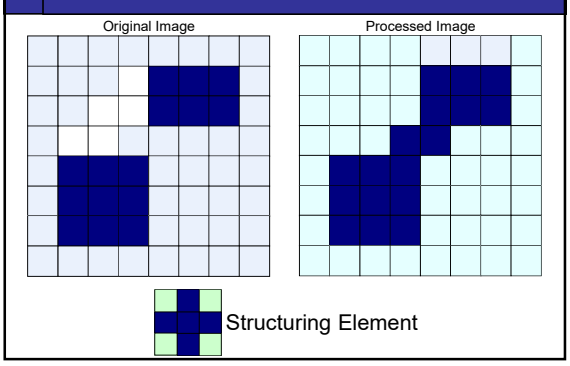
Closing Example



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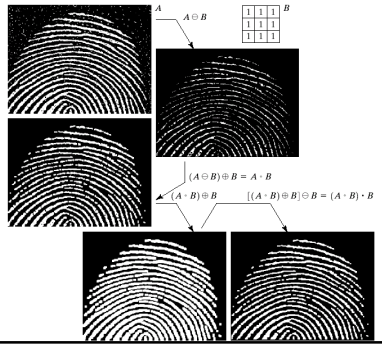
Morphological Processing Example



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

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Morphological Algorithms

Using the simple technique we have looked at so far we can begin to consider some more interesting morphological algorithms

We will look at:

- Boundary extraction
- Region filling

There are lots of others as well though:

- Extraction of connected components
- Thinning/thickening
- Skeletonisation

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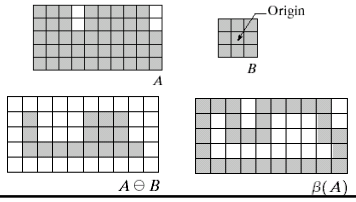
Boundary Extraction

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

The boundary can be given simply as

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



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

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Boundary Extraction Example

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

Original Image Extracted Boundary

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

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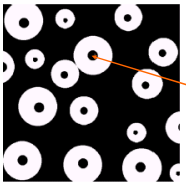
Region Filling

Given a pixel inside a boundary, *region filling* attempts to fill that boundary with object pixels (1s)



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

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

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Region Filling (cont…)

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

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

Finally the result is unioned with the original boundary

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

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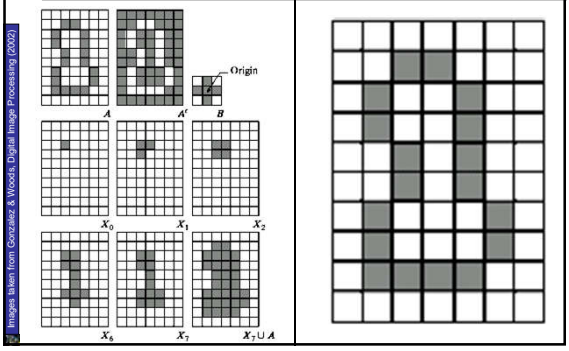
Region Filling Step By Step



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

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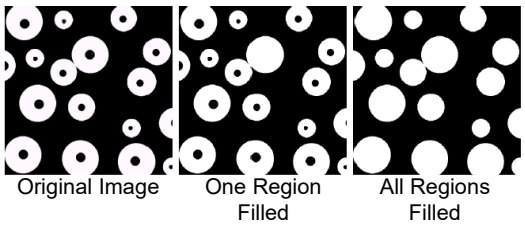
Region Filling Example



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

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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

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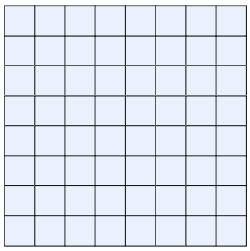
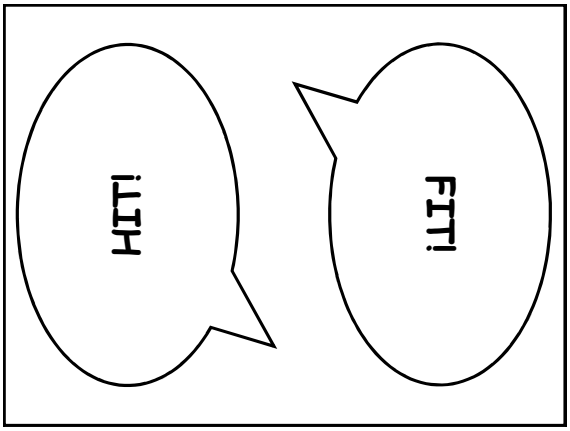
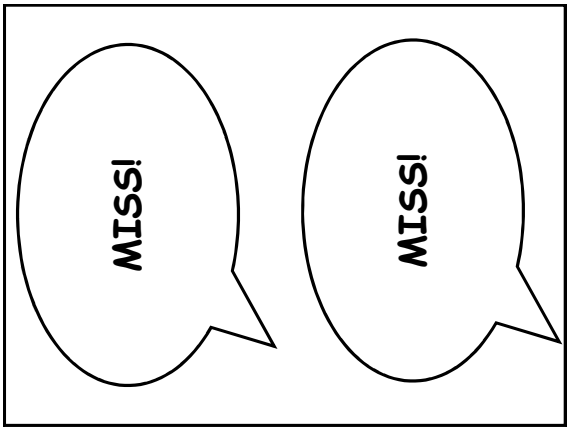
Structuring Elements, Hits & Fits







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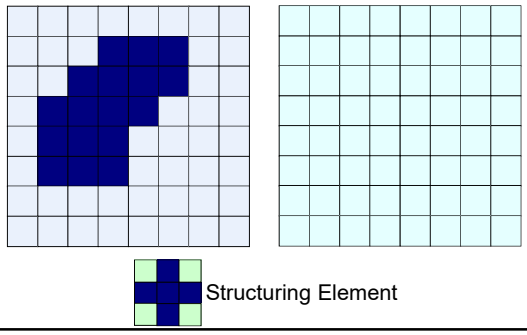
Erosion Example



Structuring Element

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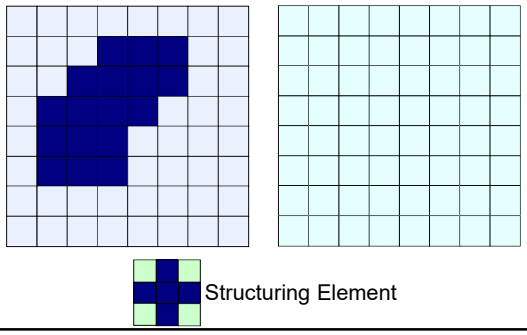
Dilation Example



Structuring Element

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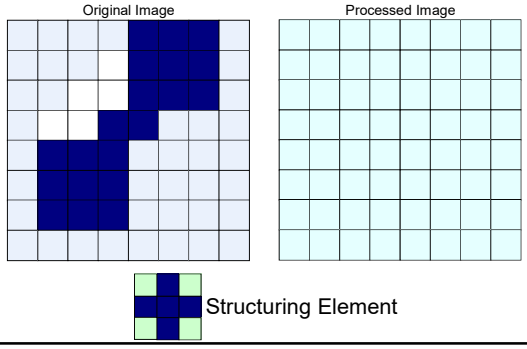
Opening Example

Original Image | Processed Image



Structuring Element

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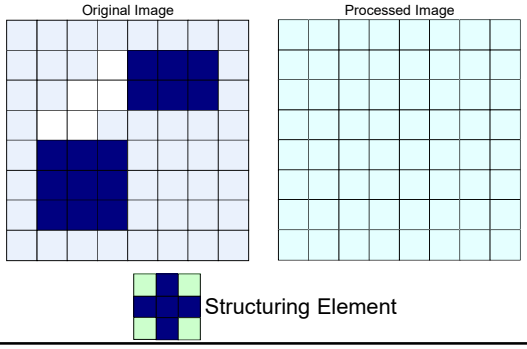
Closing Example

Original Image | Processed Image



Structuring Element

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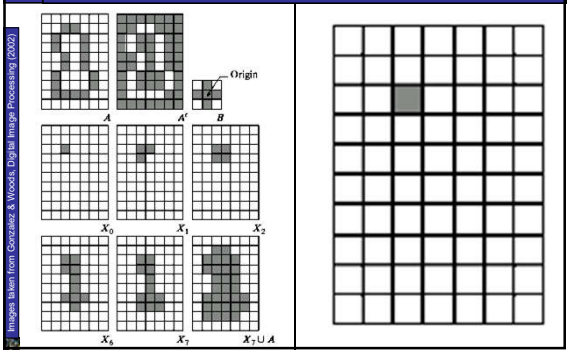
Region Filling Step By Step



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Region Filling Step By Step