ज्ञानेन प्रकाशते जगत्

INDUS UNIVERSITY

Image Processing (EC0703)

Unit-4

B.Tech (Electronics and Communication)

Semester-7

Prof.Hansa Shingrakhia

Academic Year 2019-2020

Image Segmentation: Thresholding

Contents

So far we have been considering image processing techniques used to transform images for human interpretation

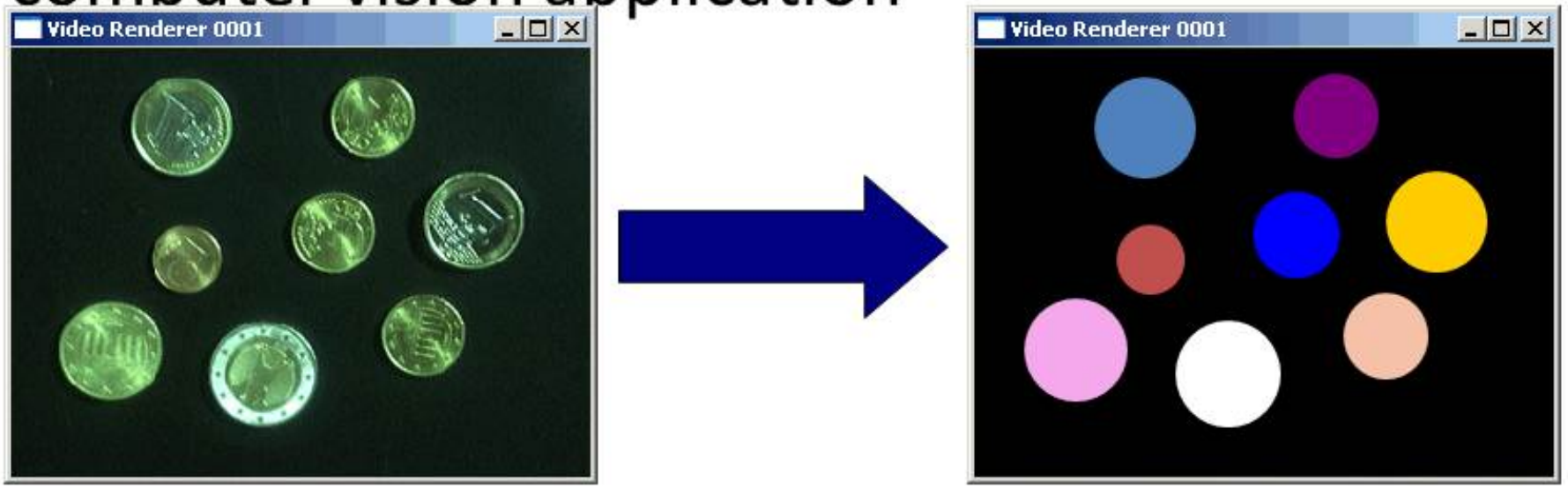
Today we will begin looking at automated image analysis by examining the thorny issue of image segmentation:

- The segmentation problem
- Finding points, lines and edges

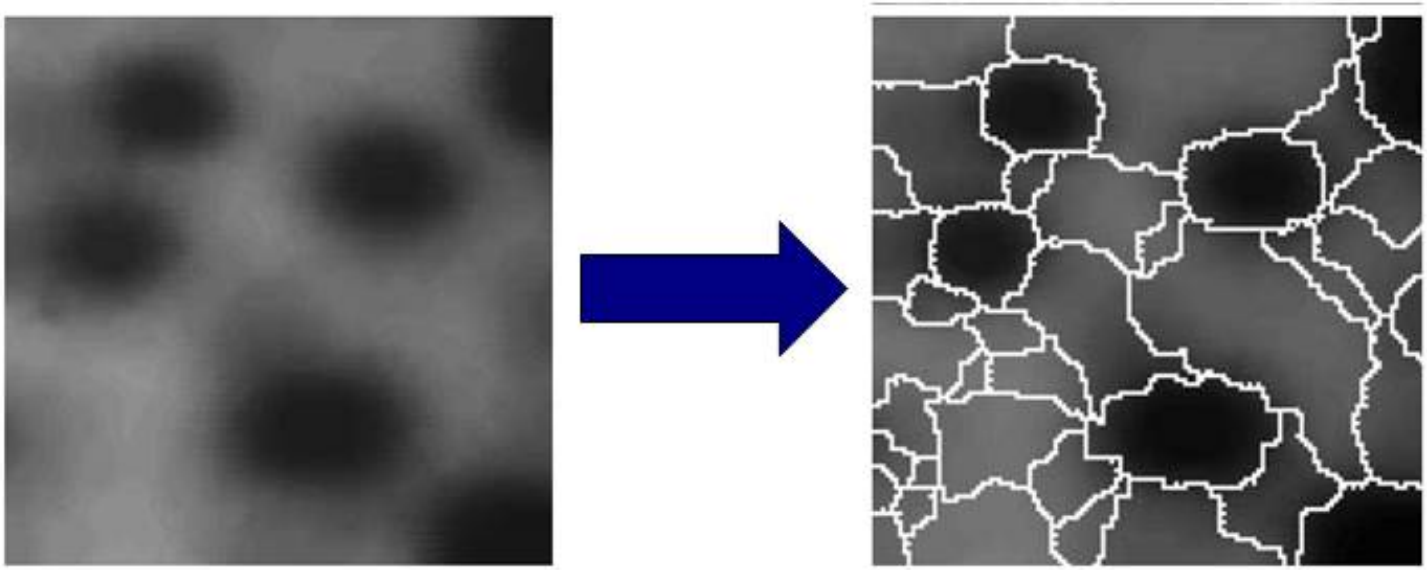
The Segmentation Problem

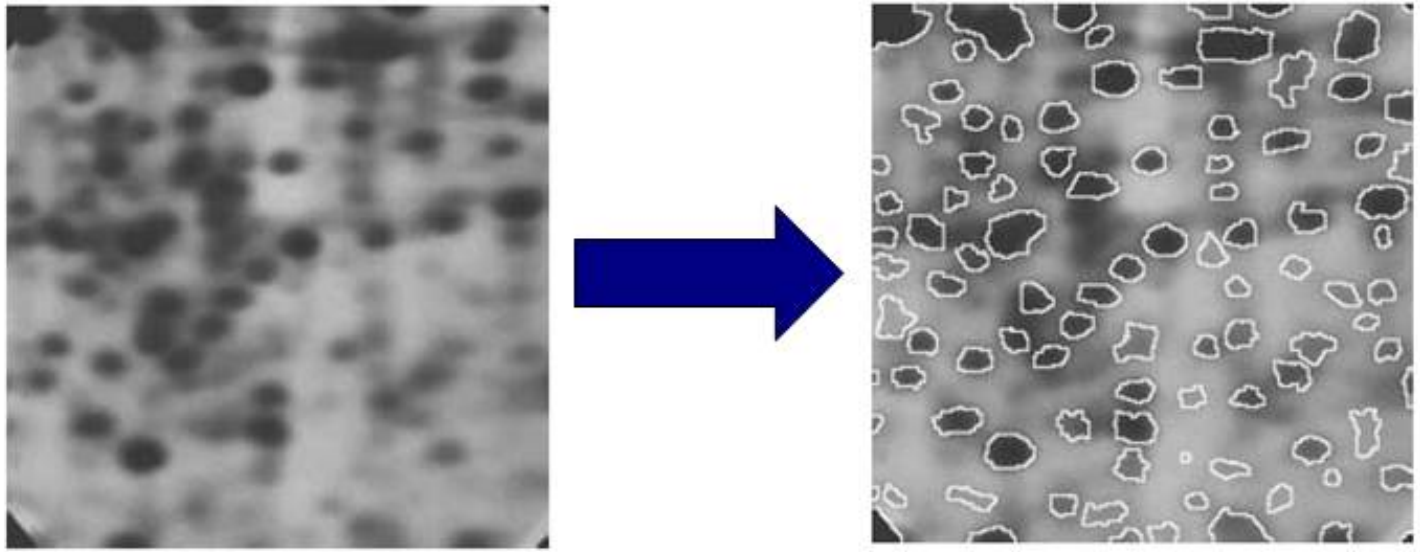
Segmentation attempts to partition the pixels of an image into groups that strongly correlate with the objects in an image

Typically the first step in any automated computer vision application



Segmentation Examples





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

Detection Of Discontinuities

There are three basic types of grey level discontinuities that we tend to look for in digital images:

- Points
- Lines
- Edges

We typically find discontinuities using masks and correlation

Point Detection

Point detection can be achieved simply using the mask below:

−1	−1	−1
−1	8	−1
−1	−1	−1

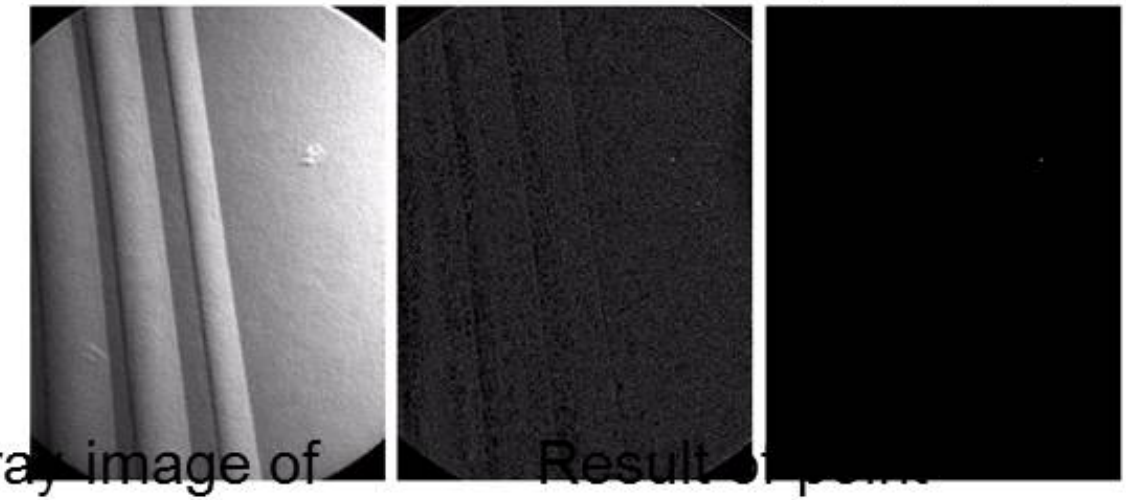
Points are detected at those pixels in the subsequent filtered image that are above a set threshold

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

Point Detection (cont…)

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

−1	−1	−1
−1	8	−1
−1	−1	−1



a
b c d

FIGURE 10.2
(a) Point detection mask. (b) X-ray image of a turbine blade with a porosity. (c) Result of point detection. (d) Result of using Eq. (10.1-2). (Original image courtesy of X-TEK Systems Ltd.)

X-ray image of a turbine blade

Result of point detection

Result of thresholding

Line Detection

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

The next level of complexity is to try to detect lines

The masks below will extract lines that are one pixel thick and running in a particular direction

−1	−1	−1
2	2	2
−1	−1	−1

Horizontal

−1	−1	2
−1	2	−1
2	−1	−1

+45°

−1	2	−1
−1	2	−1
−1	2	−1

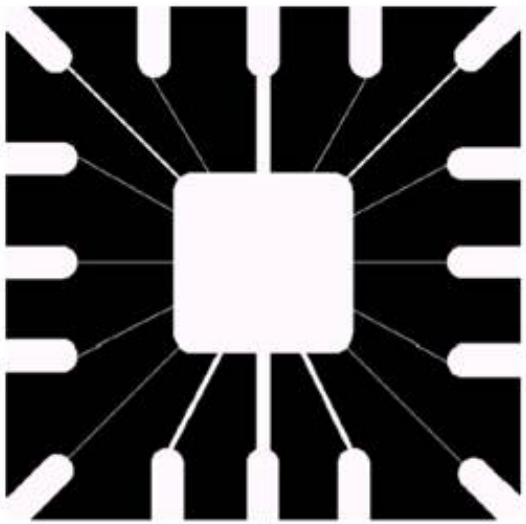
Vertical

2	−1	−1
−1	2	−1
−1	−1	2

−45°

Line Detection (cont…)

Binary image of a wire bond mask



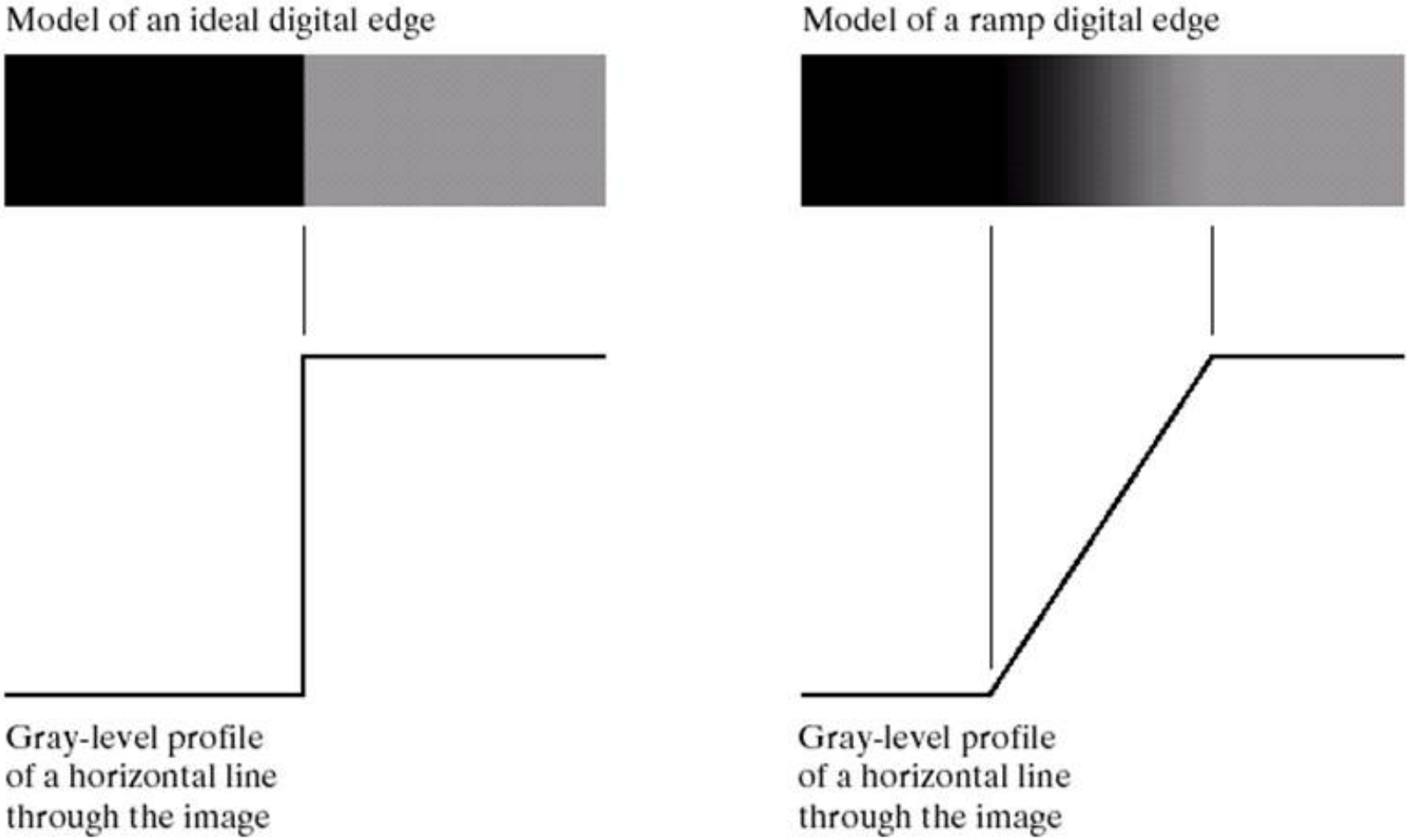
After processing with -45° line detector

Result of thresholding filtering result

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

Edge Detection

An edge is a set of connected pixels that lie on the boundary between two regions



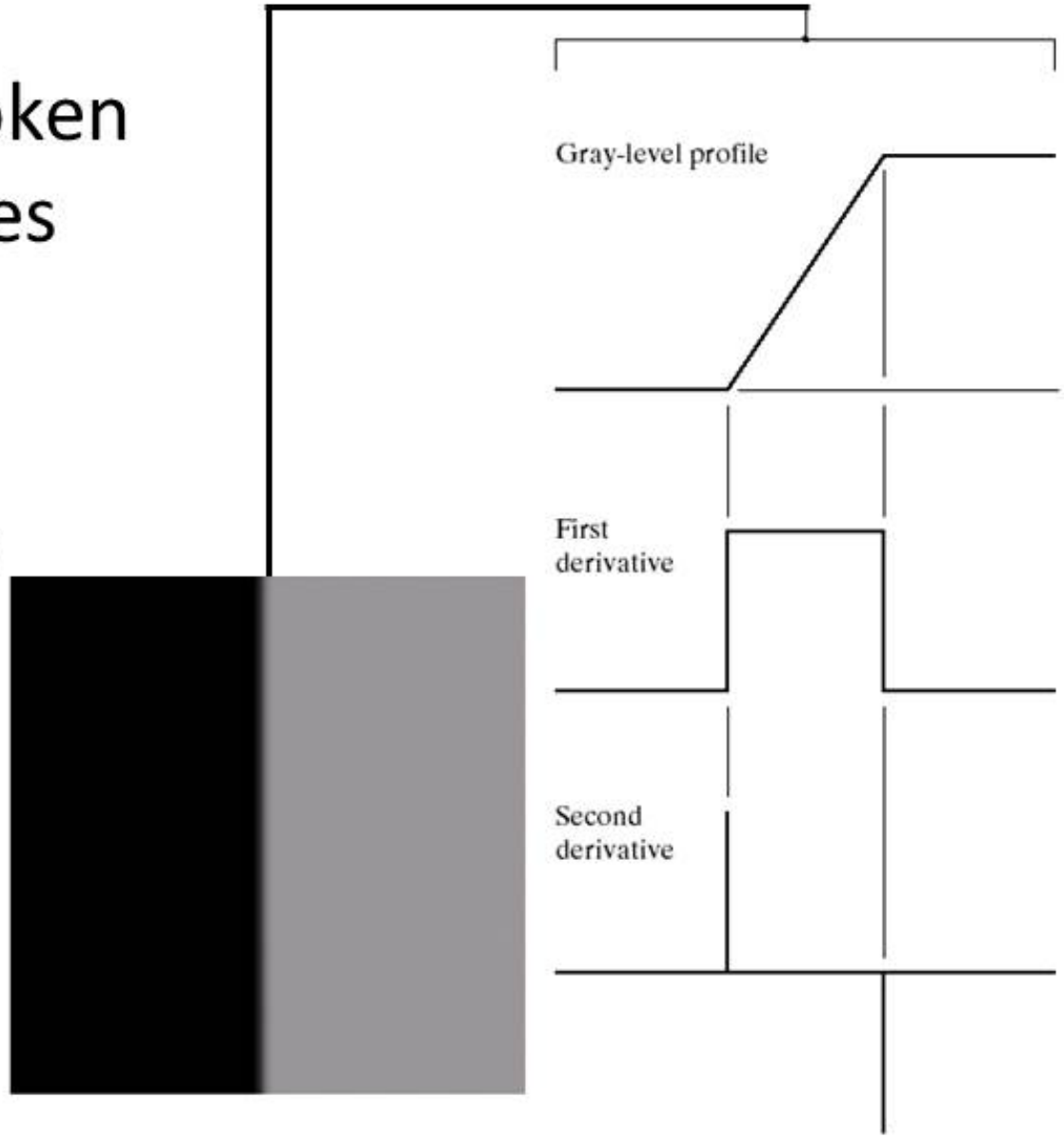
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Edges & Derivatives

We have already spoken about how derivatives are used to find discontinuities

1st derivative tells us where an edge is

2nd derivative can be used to show edge direction

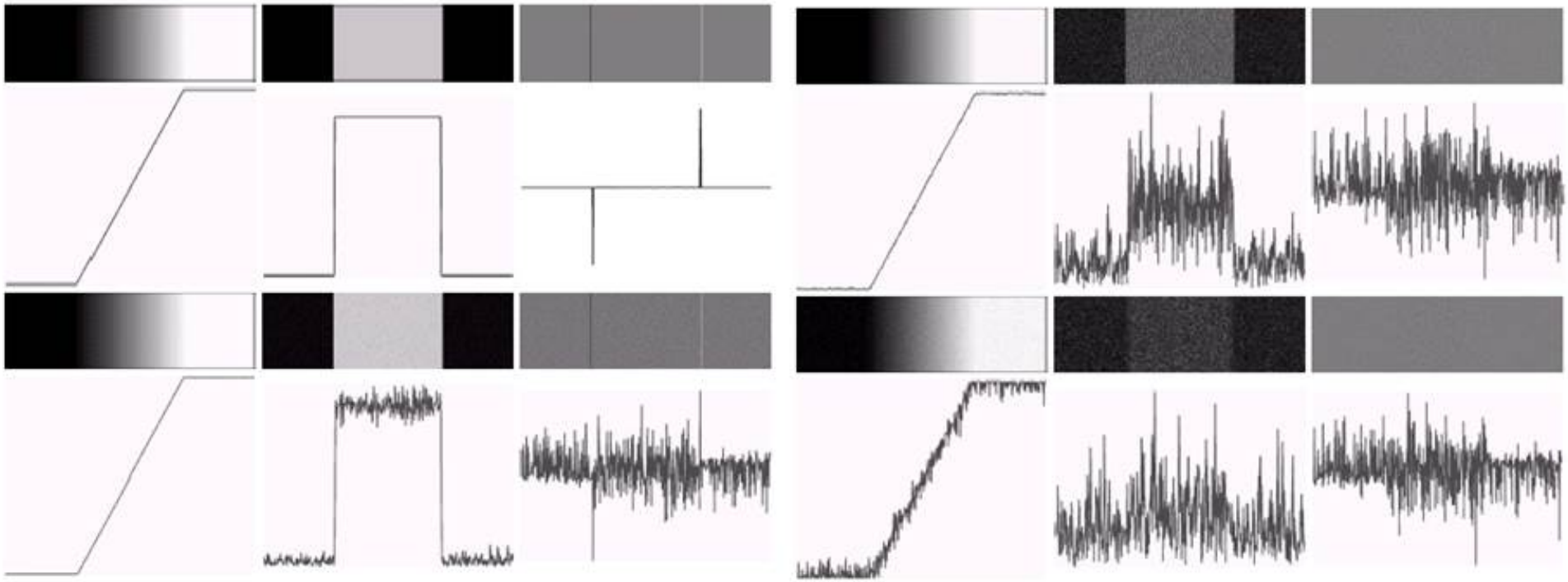


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Derivatives & Noise

Derivative based edge detectors are extremely sensitive to noise

We need to keep this in mind



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

Common Edge Detectors

Given a 3*3 region of an image the following edge detection filters can be used

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

−1	−1	−1
0	0	0
1	1	1

−1	0	1
−1	0	1
−1	0	1

Prewitt

−1	0
0	1

0	−1
1	0

Roberts

−1	−2	−1
0	0	0
1	2	1

−1	0	1
−2	0	2
−1	0	1

Sobel

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

Edge Detection Example

Original Image

Horizontal Gradient Component

Vertical Gradient Component

Combined Edge Image

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

Edge Detection Example

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Edge Detection Example

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Edge Detection Example

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Edge Detection Problems

Often, problems arise in edge detection in that there are is too much detail

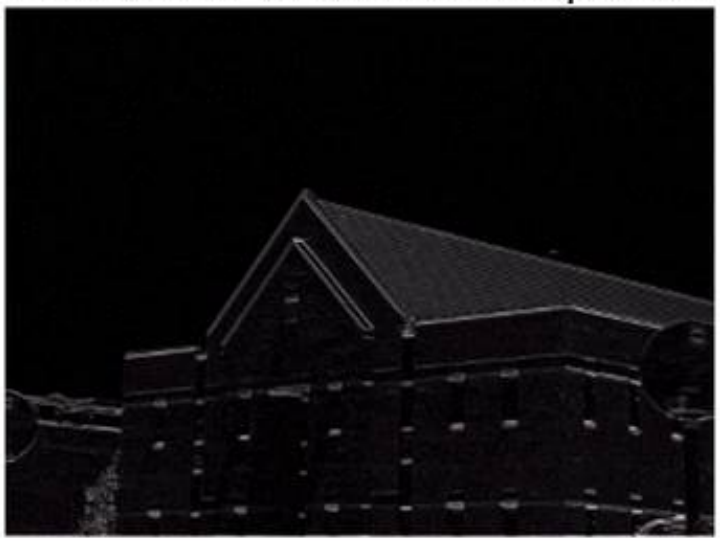
For example, the brickwork in the previous example

One way to overcome this is to smooth images prior to edge detection

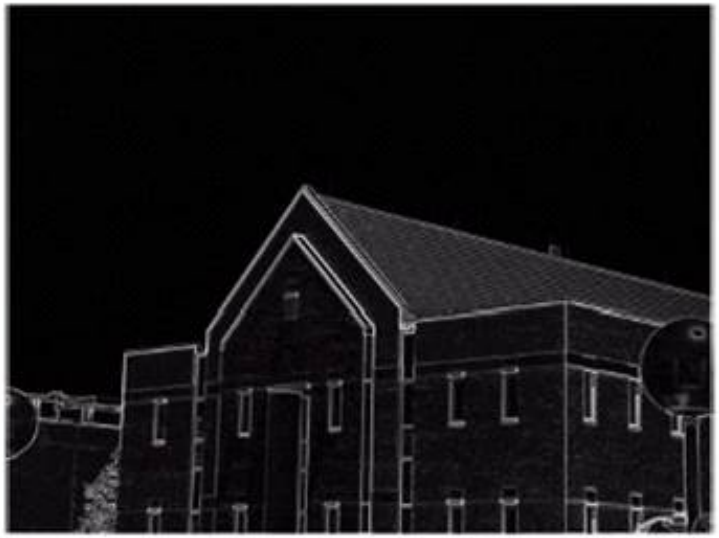
Edge Detection Example With Smoothing

Original Image

Horizontal Gradient Component



Vertical Gradient Component



Combined Edge Image

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

Laplacian Edge Detection

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

We encountered the 2nd-order derivative based Laplacian filter already

0	−1	0
−1	4	−1
0	−1	0

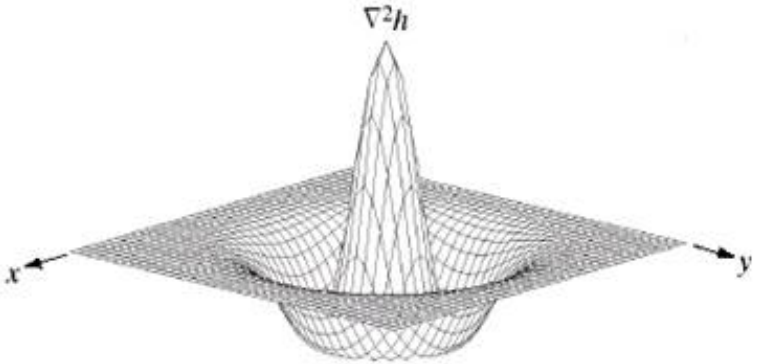
−1	−1	−1
−1	8	−1
−1	−1	−1

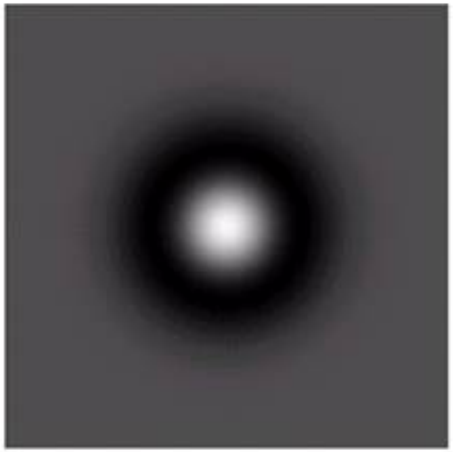
The Laplacian is typically not used by itself as it is too sensitive to noise

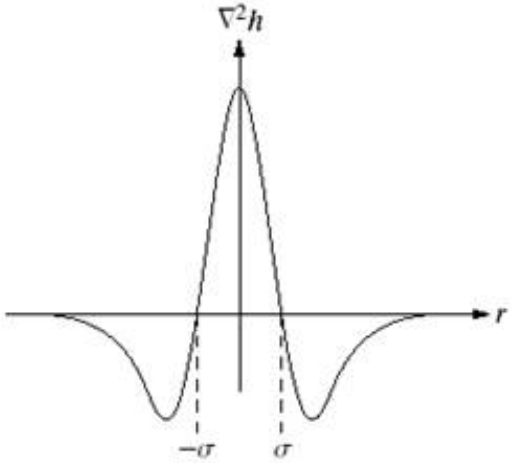
Usually hen used for edge detection the Laplacian is combined with a smoothing Gaussian filter

Laplacian Of Gaussian

The Laplacian of Gaussian (or Mexican hat) filter uses the Gaussian for noise removal and the Laplacian for edge detection



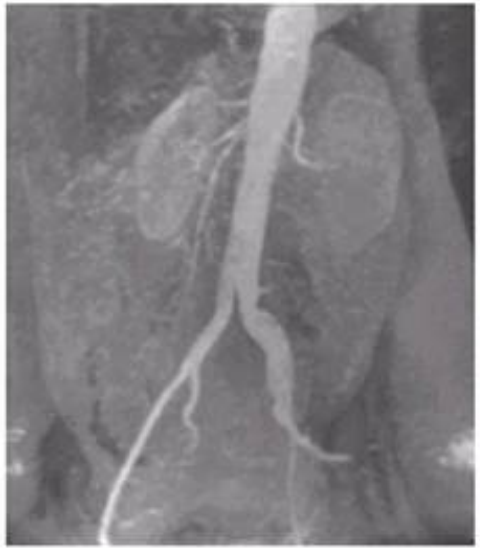


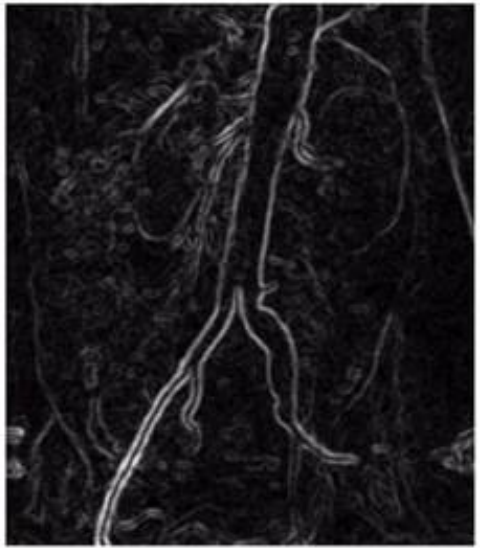


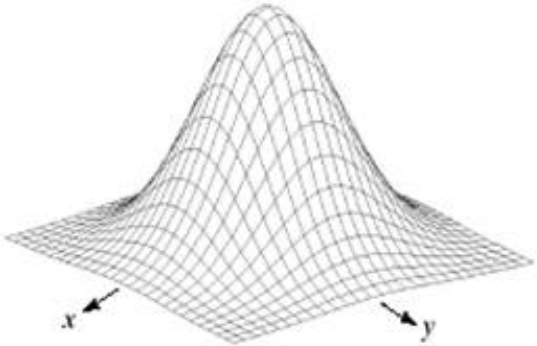
0	0	−1	0	0
0	−1	−2	−1	0
−1	−2	16	−2	−1
0	−1	−2	−1	0
0	0	−1	0	0

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

Laplacian Of Gaussian Example







−1	−1	−1
−1	8	−1
−1	−1	−1

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

Summary

In this lecture we have begun looking at segmentation, and in particular edge detection

Edge detection is massively important as it is in many cases the first step to object recognition

Contents

Today we will continue to look at the problem of segmentation, this time though in terms of thresholding

In particular we will look at:

- What is thresholding?
- Simple thresholding
- Adaptive thresholding

Thresholding

Thresholding is usually the first step in any segmentation approach

We have talked about simple single value thresholding already

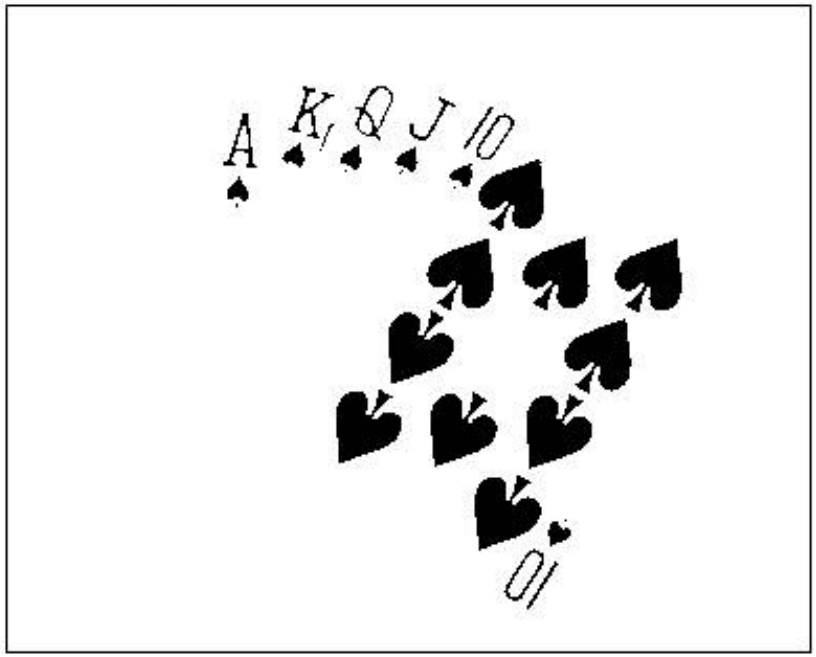
Single value thresholding can be given mathematically as follows:

$$g(x,y) = \begin{cases} 1 \; if \;\; f(x,y) > T \\ 0 \; if \;\; f(x,y) \leq T \end{cases}$$

Thresholding Example

Imagine a poker playing robot that needs to visually interpret the cards in its hand

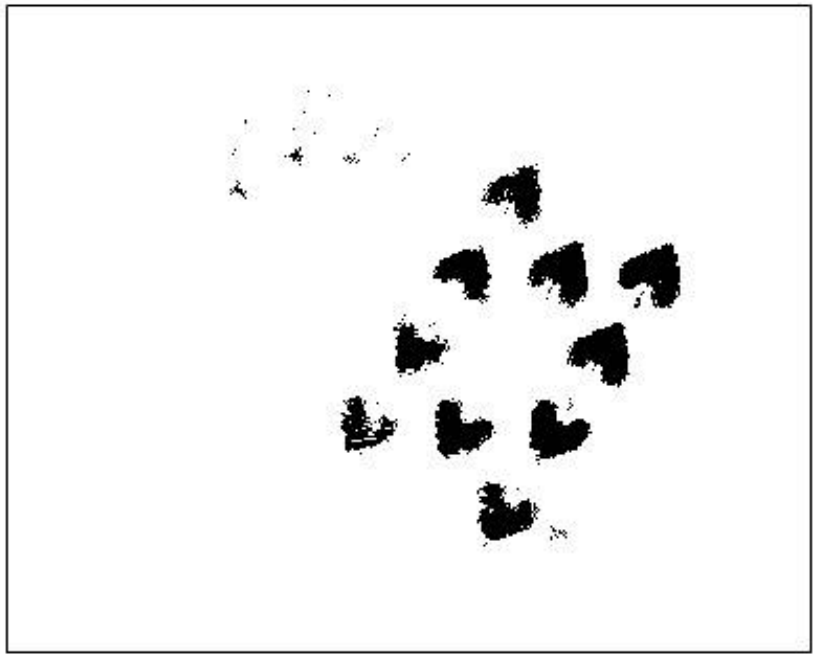
Original Image



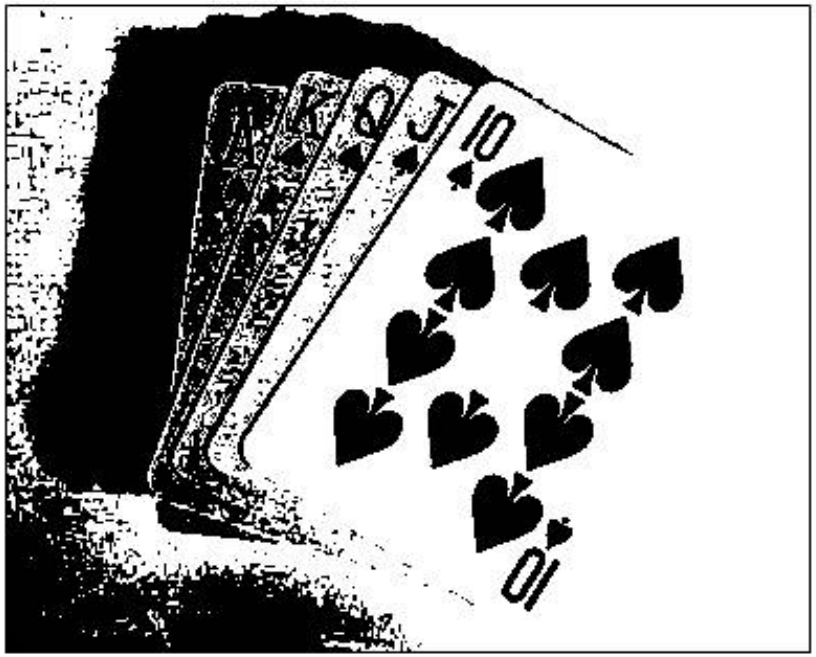
Thresholded Image

But Be Careful

If you get the threshold wrong the results can be disastrous



Threshold Too Low



Threshold Too High

Basic Global Thresholding

Based on the histogram of an image

Partition the image histogram using a single global threshold

The success of this technique very strongly depends on how well the histogram can be partitioned

Basic Global Thresholding Algorithm

The basic global threshold, T, is calculated as follows:

1. Select an initial estimate for T (typically the average grey level in the image)
2. Segment the image using T to produce two groups of pixels: G_1 consisting of pixels with grey levels >T and G_2 consisting pixels with grey levels ≤ T
3. Compute the average grey levels of pixels in G_1 to give μ_1 and G_2 to give μ_2

Basic Global Thresholding Algorithm

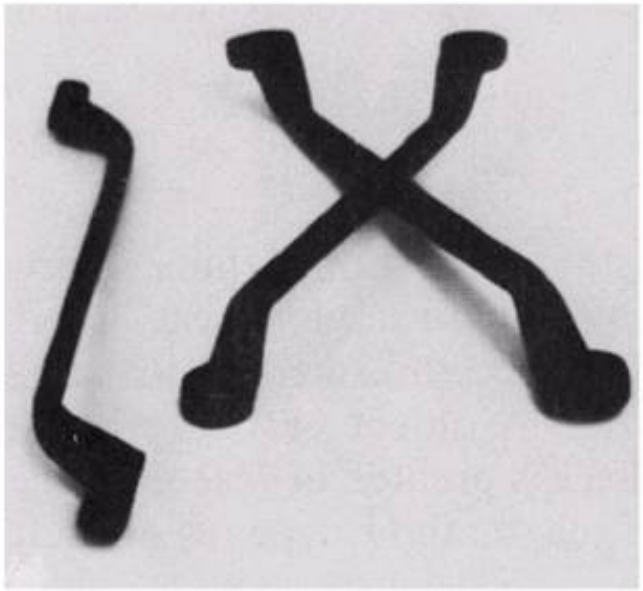
4. Compute a new threshold value:

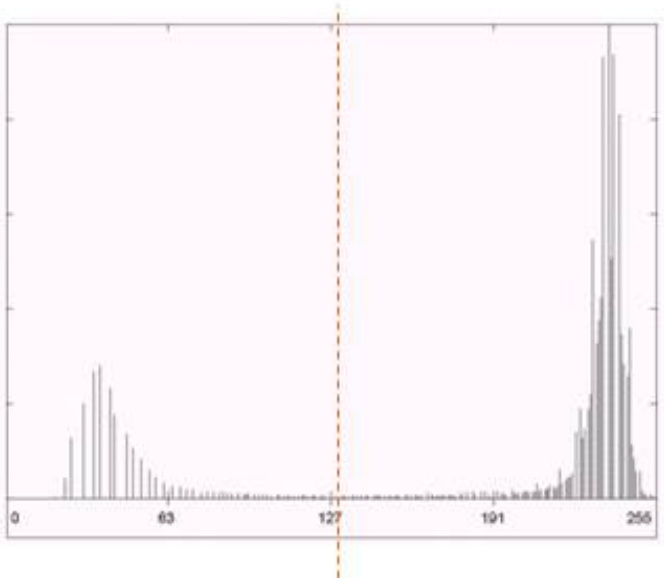
$$T = \frac{\mu_1 + \mu_2}{2}$$

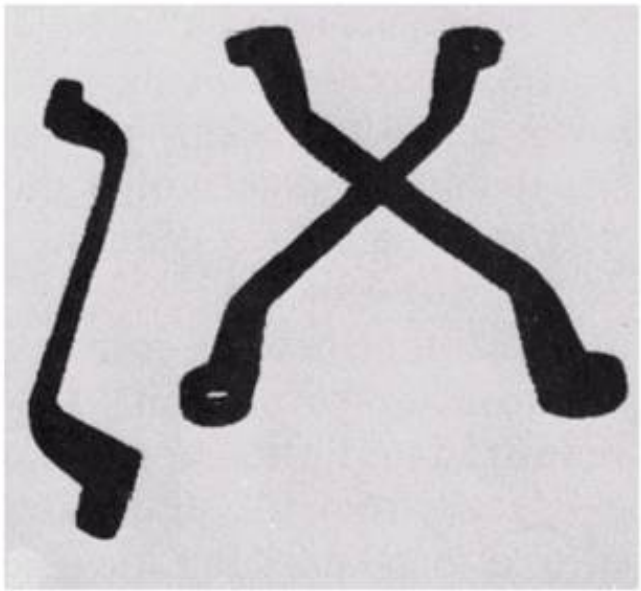
5. Repeat steps 2 – 4 until the difference in T in successive iterations is less than a predefined limit T_∞

This algorithm works very well for finding thresholds when the histogram is suitable

Thresholding Example 1

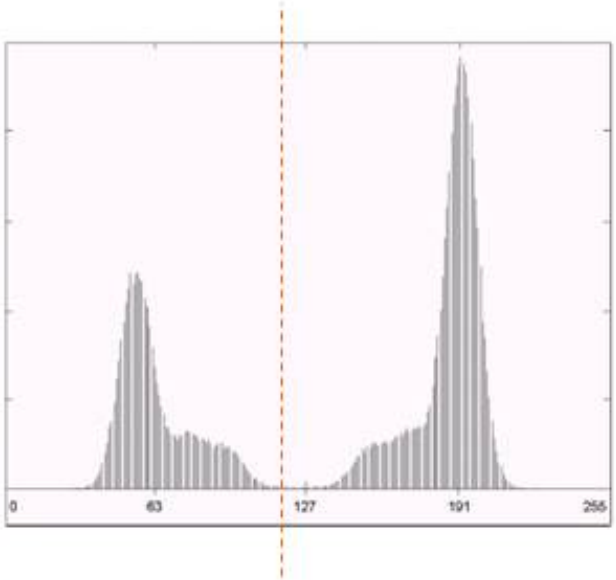






Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Thresholding Example 2

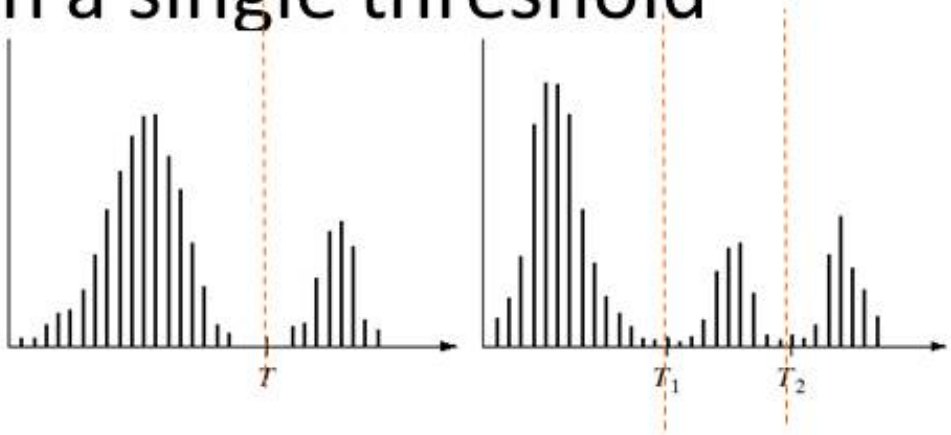


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Problems With Single Value Thresholding

Single value thresholding only works for bimodal histograms

Images with other kinds of histograms need more than a single threshold



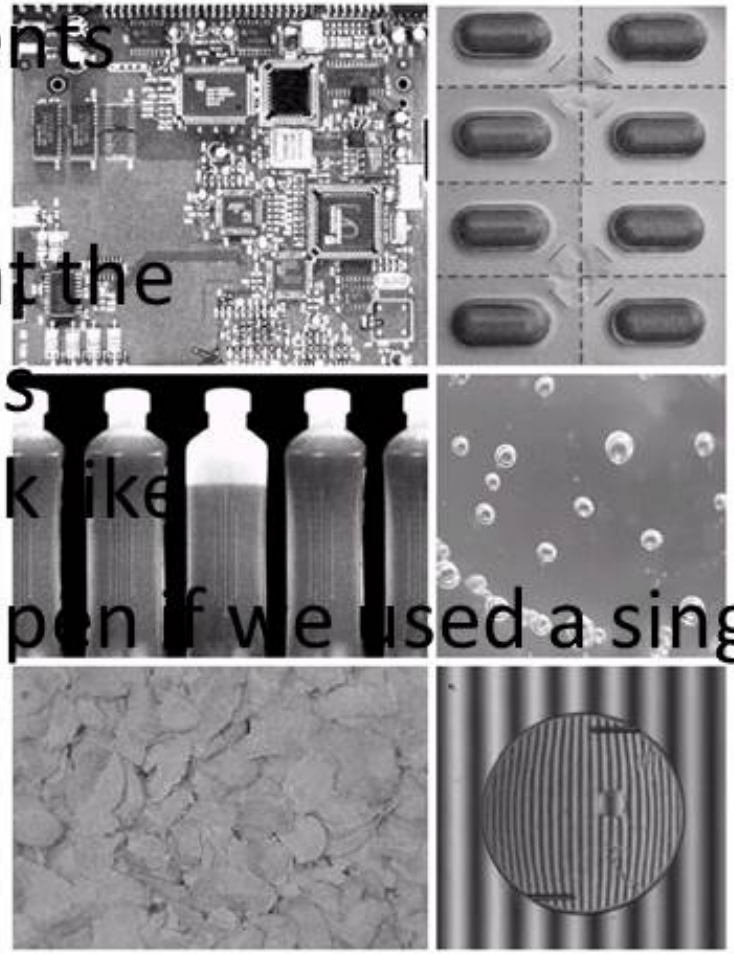
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Problems With Single Value Thresholding (cont…)

Let's say we want to isolate the contents of the bottles.

Think about what the histogram for this image would look like.

What would happen if we used a single threshold value?

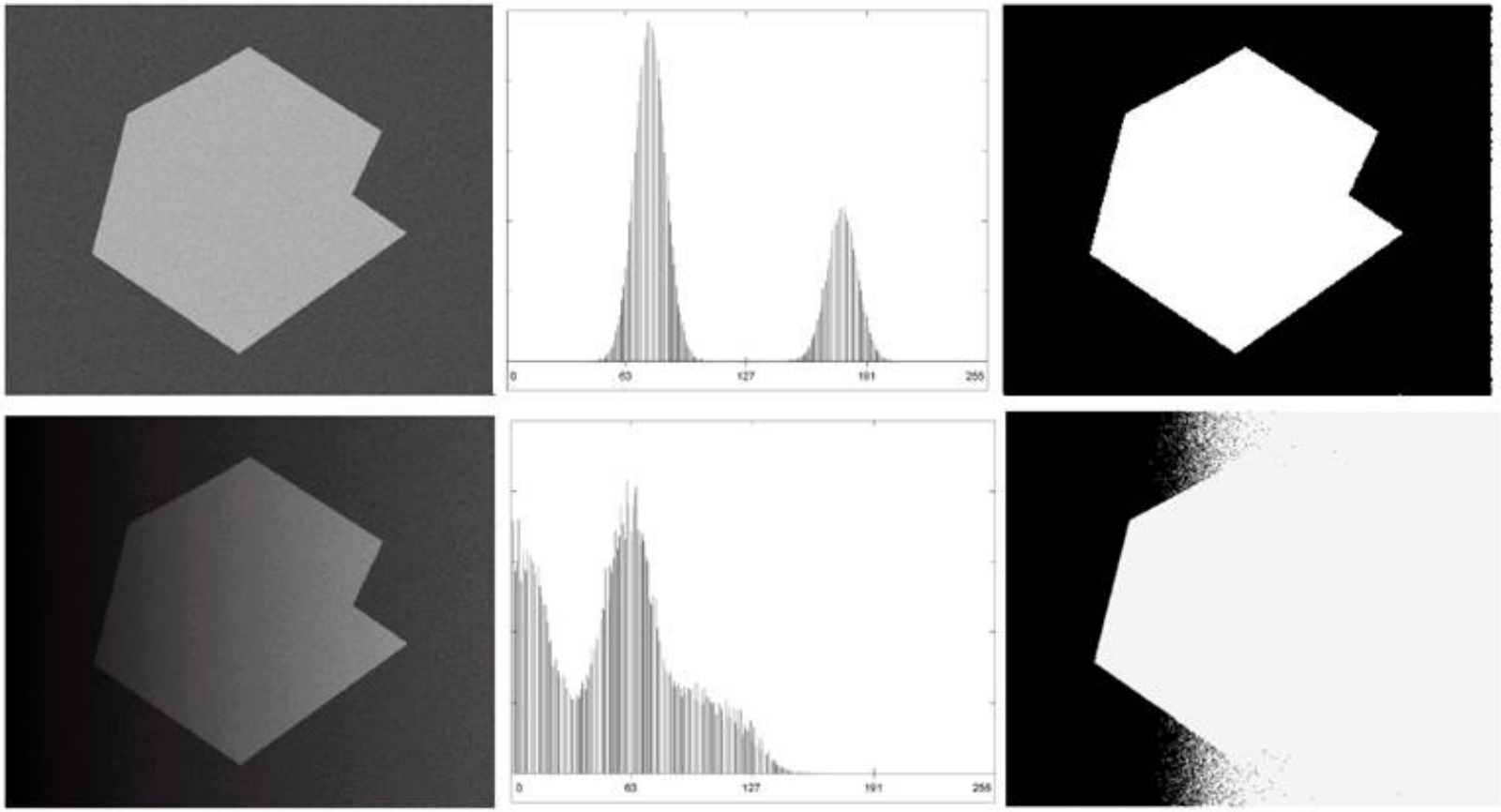


a b
c d

FIGURE 1.14 Some examples of manufactured goods often checked using digital image processing. (a) A circuit board controller. (b) Packaged pills. (c) Bottles. (d) Bubbles in clear-plastic product. (e) Cereal. (f) Image of intraocular implant. (Figs. (f) courtesy of Mr. [illegible], Sid-Tech Inspection Corporation.)

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

Single Value Thresholding and Illumination



Uneven illumination can really upset a single valued thresholding scheme

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

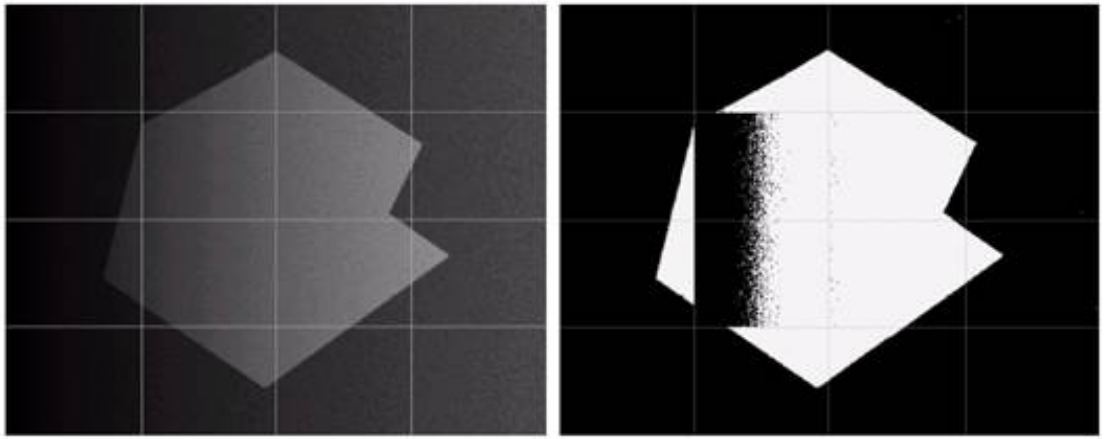
Basic Adaptive Thresholding

An approach to handling situations in which single value thresholding will not work is to divide an image into sub images and threshold these individually

Since the threshold for each pixel depends on its location within an image this technique is said to *adaptive*

Basic Adaptive Thresholding Example

The image below shows an example of using adaptive thresholding with the image shown previously



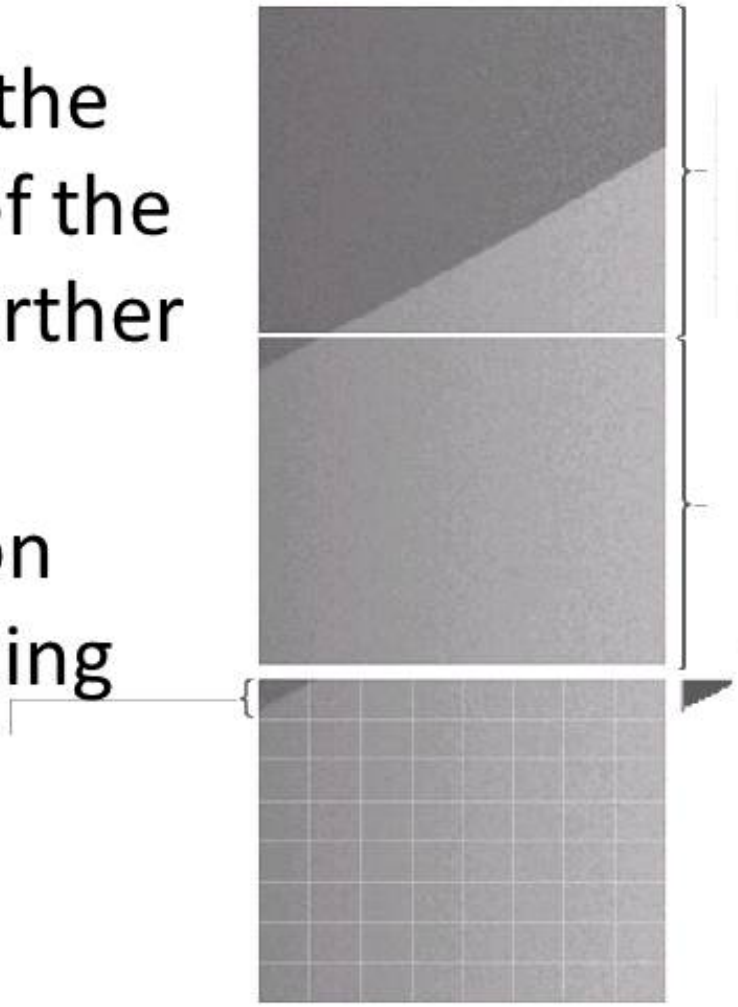
As can be seen success is mixed

But, we can further subdivide the troublesome sub images for more success

Basic Adaptive Thresholding Example (cont…)

These images show the troublesome parts of the previous problem further subdivided

After this sub division successful thresholding can be achieved



Summary

In this lecture we have begun looking at segmentation, and in particular thresholding

We saw the basic global thresholding algorithm and its shortcomings

We also saw a simple way to overcome some of these limitations using adaptive thresholding

Digital Image Processing

Image Segmentation: Thresholding

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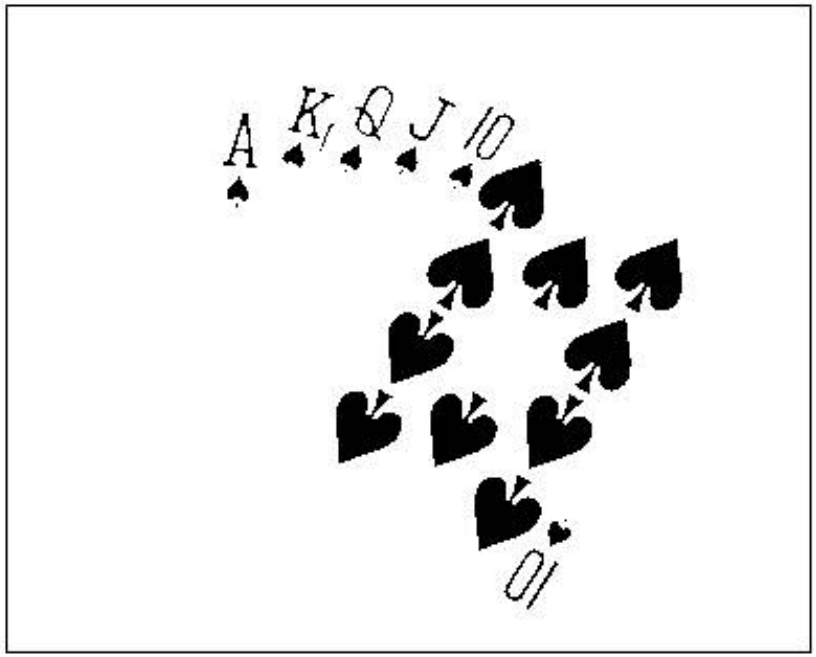

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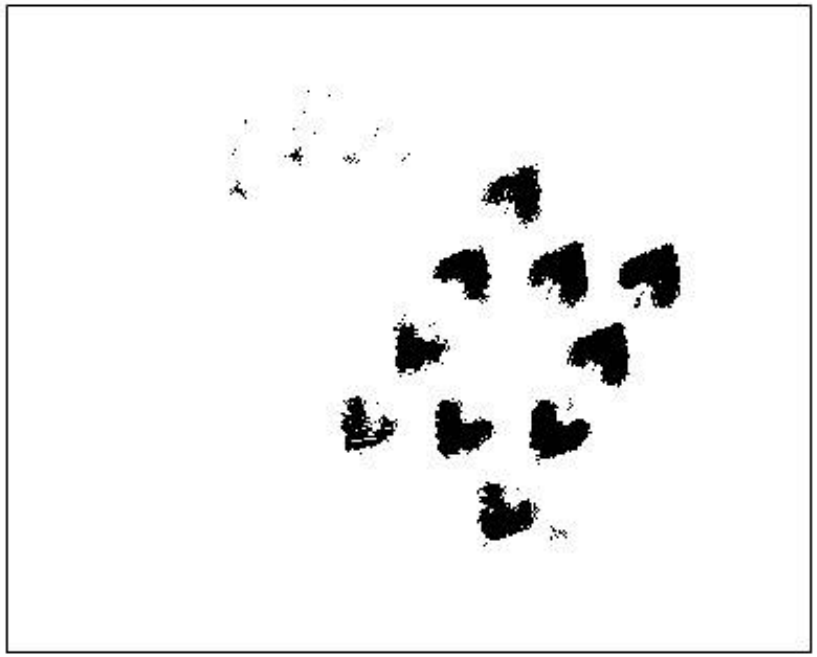

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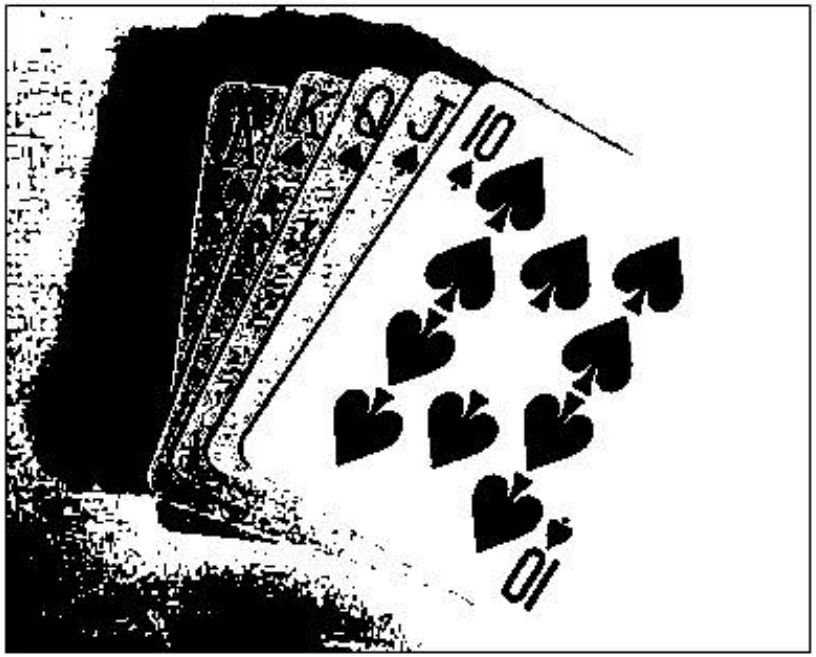

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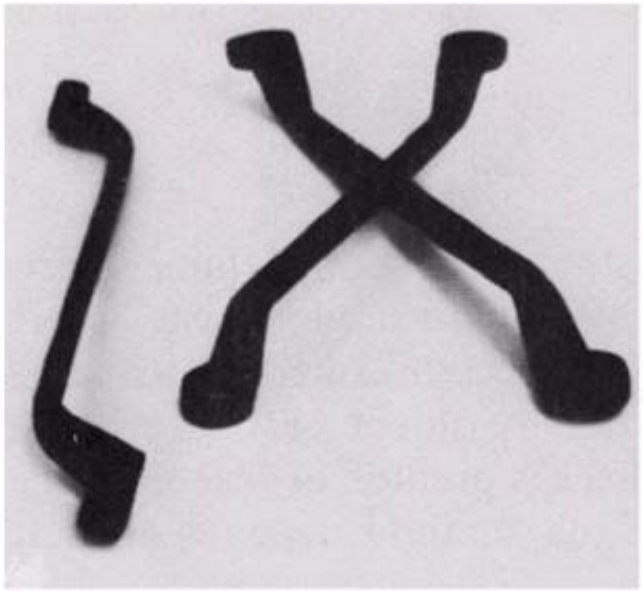
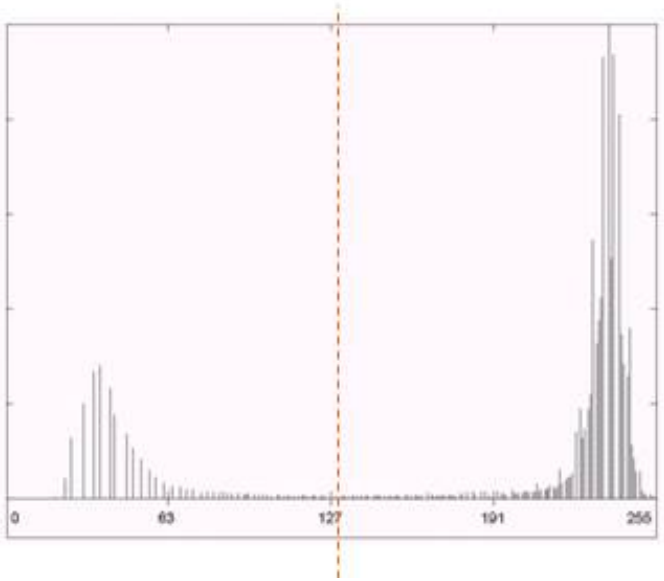
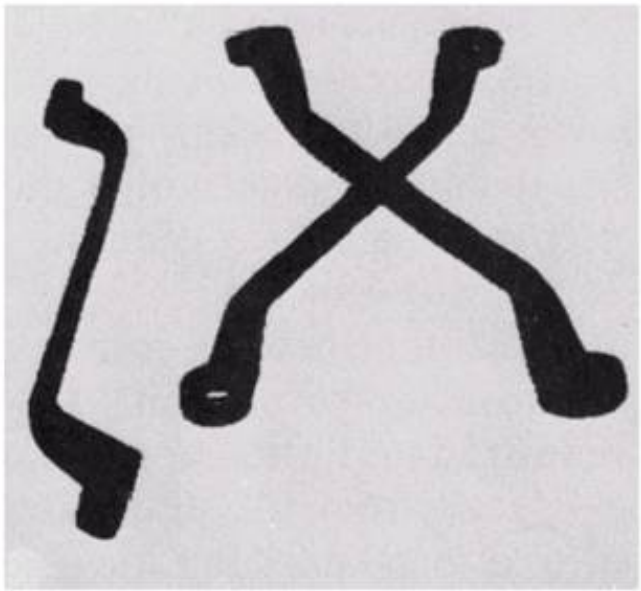
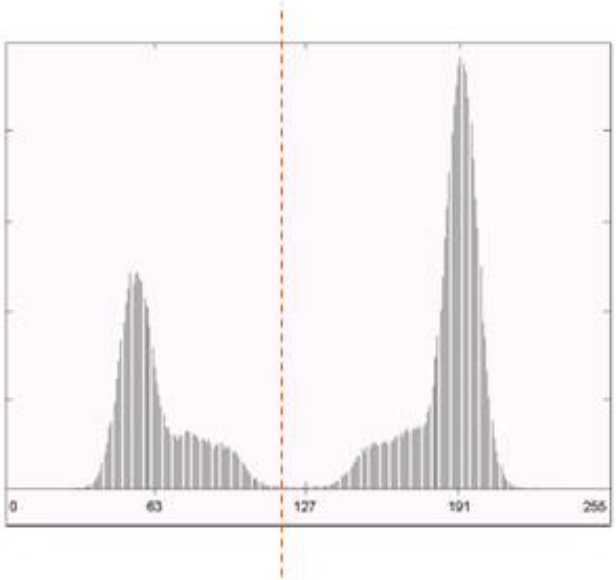






Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Thresholding Example 2



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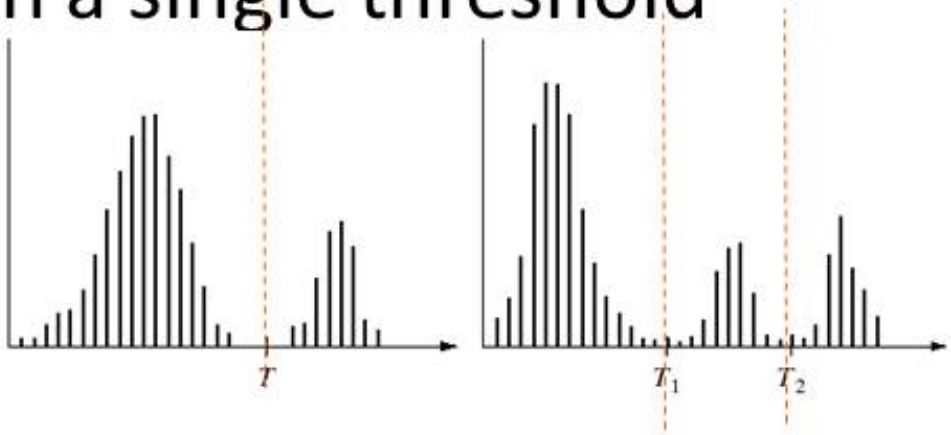
Single value thresholding only works for bimodal histograms

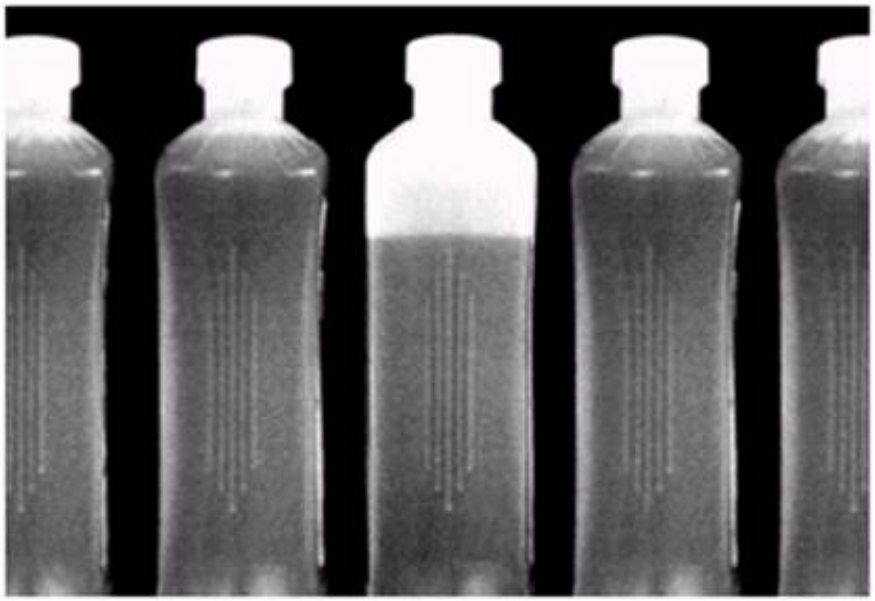
Images with other kinds of histograms need more than a single threshold



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

Problems With Single Value Thresholding (cont…)

Let's say we want to isolate the contents of the bottles

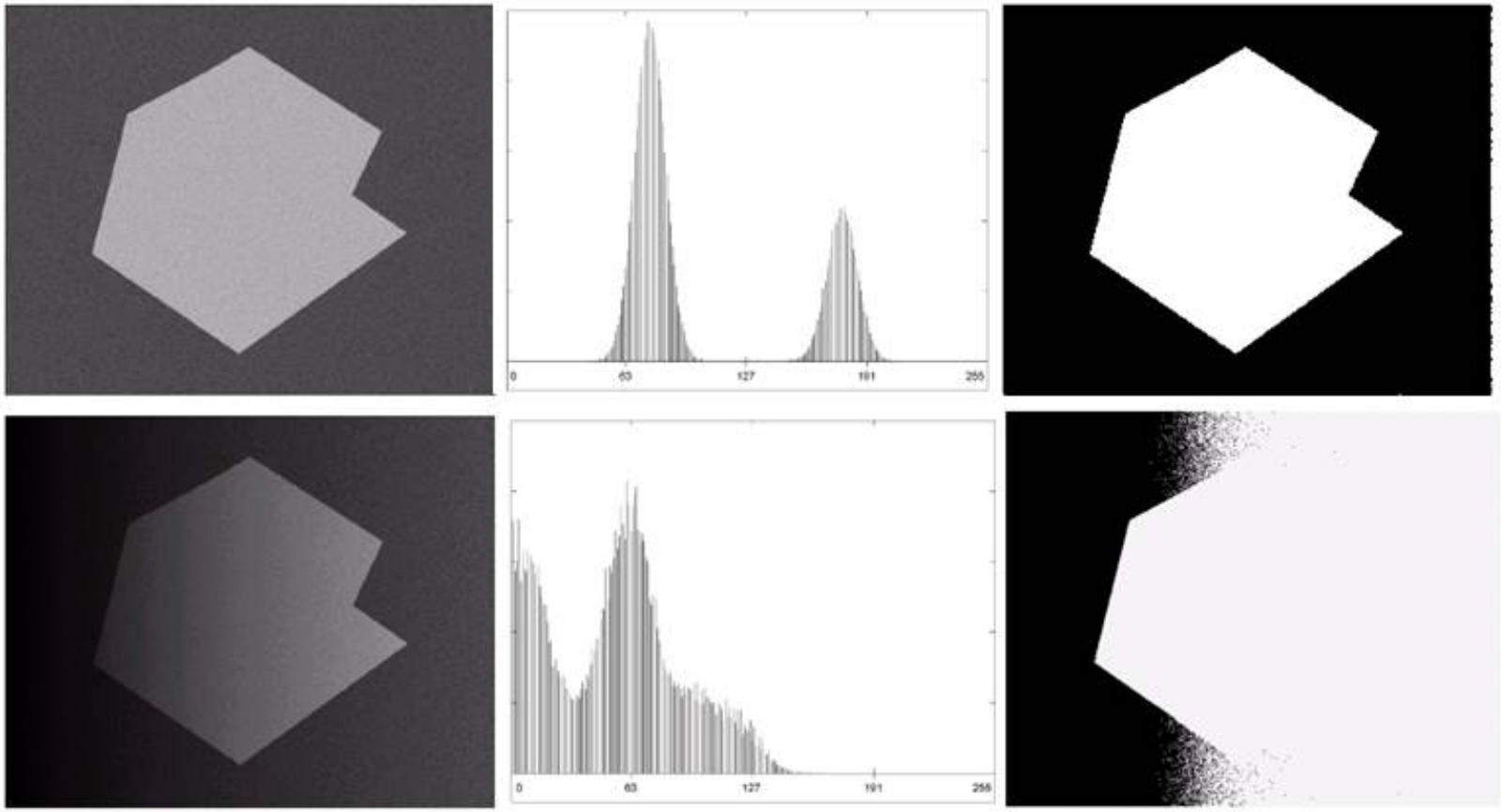


Think about what the histogram for this image would look like

What would happen if we used a single threshold value?

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

Single Value Thresholding and Illumination



Uneven illumination can really upset a single valued thresholding scheme

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

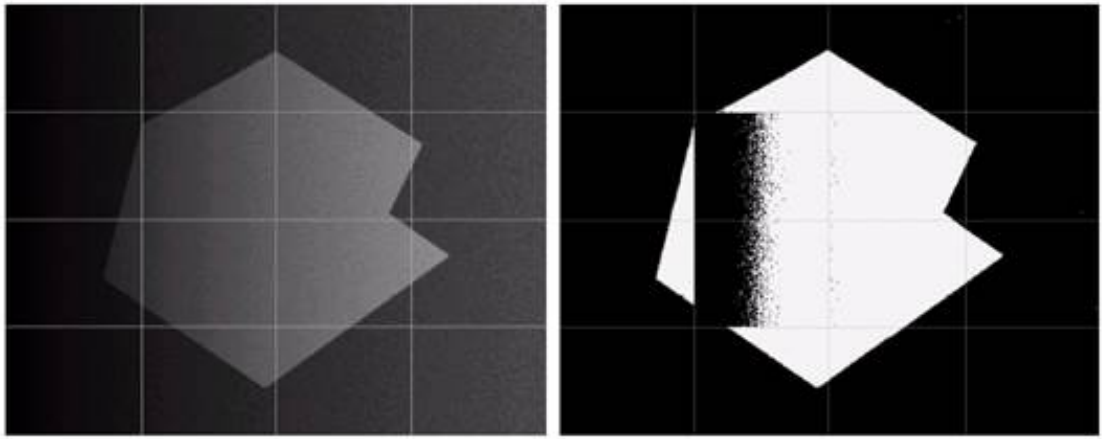
Basic Adaptive Thresholding

An approach to handling situations in which single value thresholding will not work is to divide an image into sub images and threshold these individually

Since the threshold for each pixel depends on its location within an image this technique is said to *adaptive*

Basic Adaptive Thresholding Example

The image below shows an example of using adaptive thresholding with the image shown previously



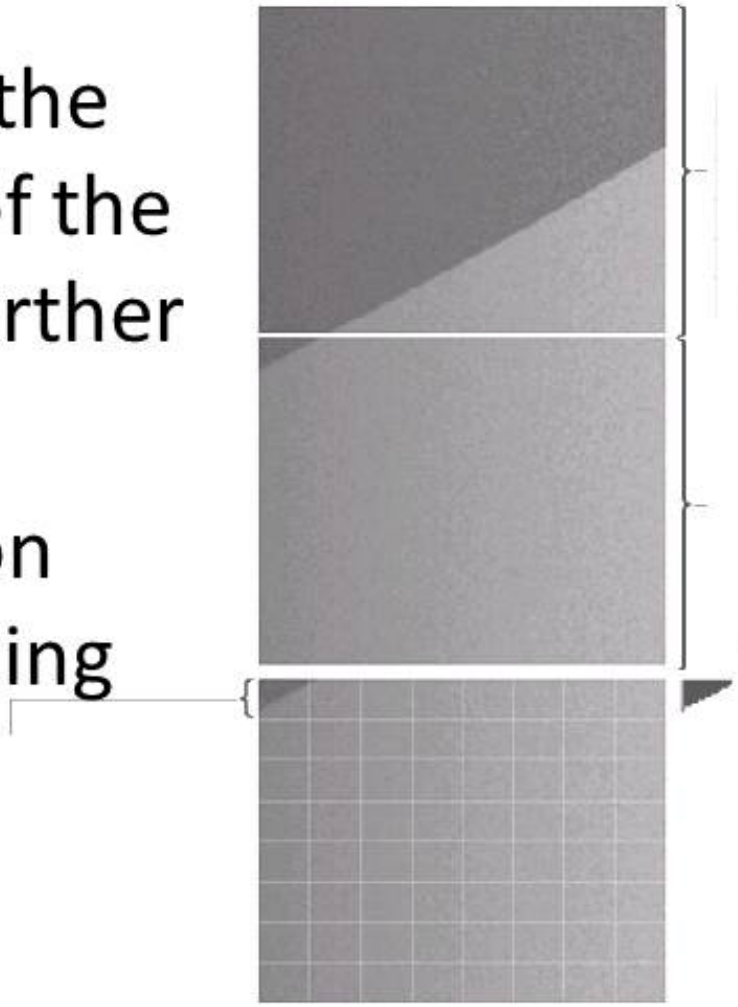
As can be seen success is mixed

But, we can further subdivide the troublesome sub images for more success

Basic Adaptive Thresholding Example (cont…)

These images show the troublesome parts of the previous problem further subdivided

After this sub division successful thresholding can be achieved



Summary

In this lecture we have begun looking at segmentation, and in particular thresholding

We saw the basic global thresholding algorithm and its shortcomings

We also saw a simple way to overcome some of these limitations using adaptive thresholding

Digital Image Processing

Morphological Image Processing

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

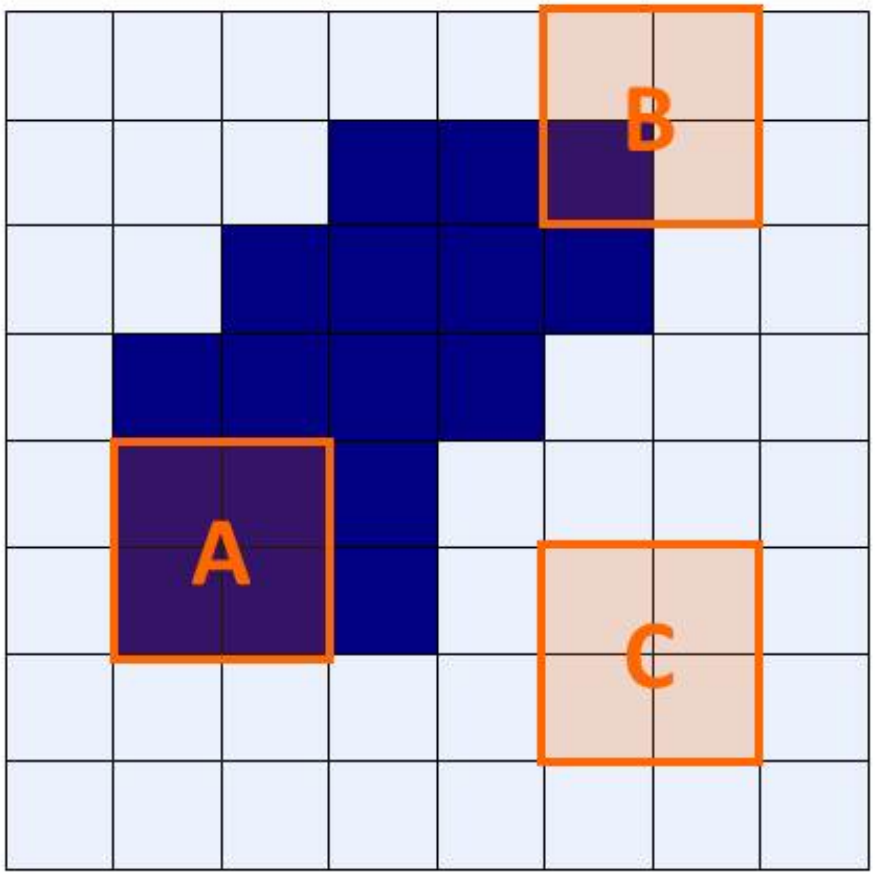
Quick Example

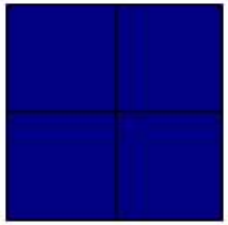
Image after segmentation

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

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

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

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**

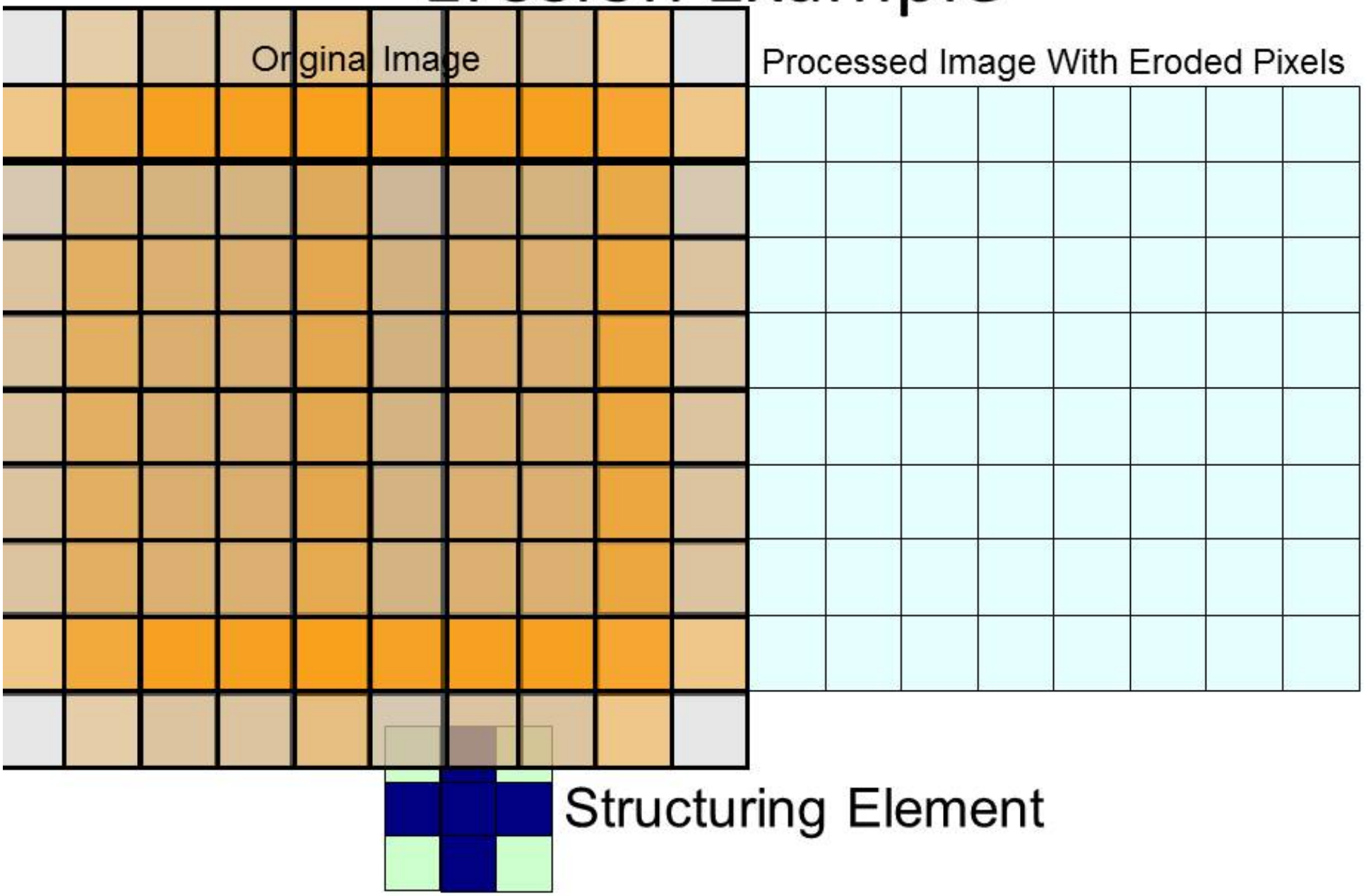
Erosion

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:

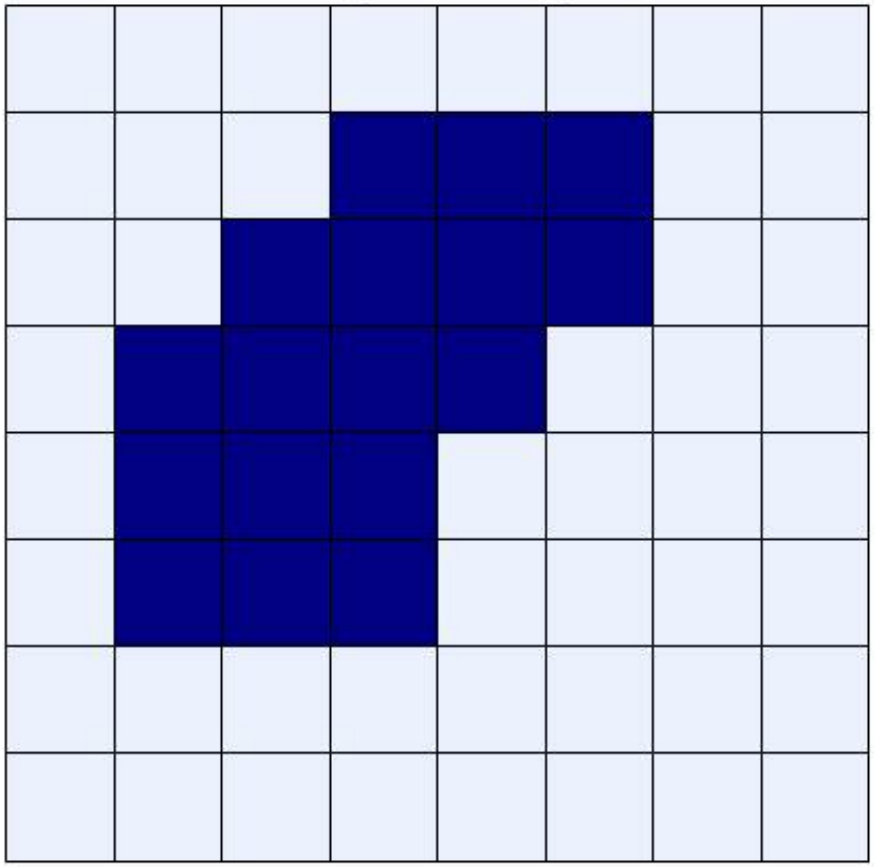
$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ fits } f \\ 0 \text{ otherwise} \end{cases}$$

Erosion Example

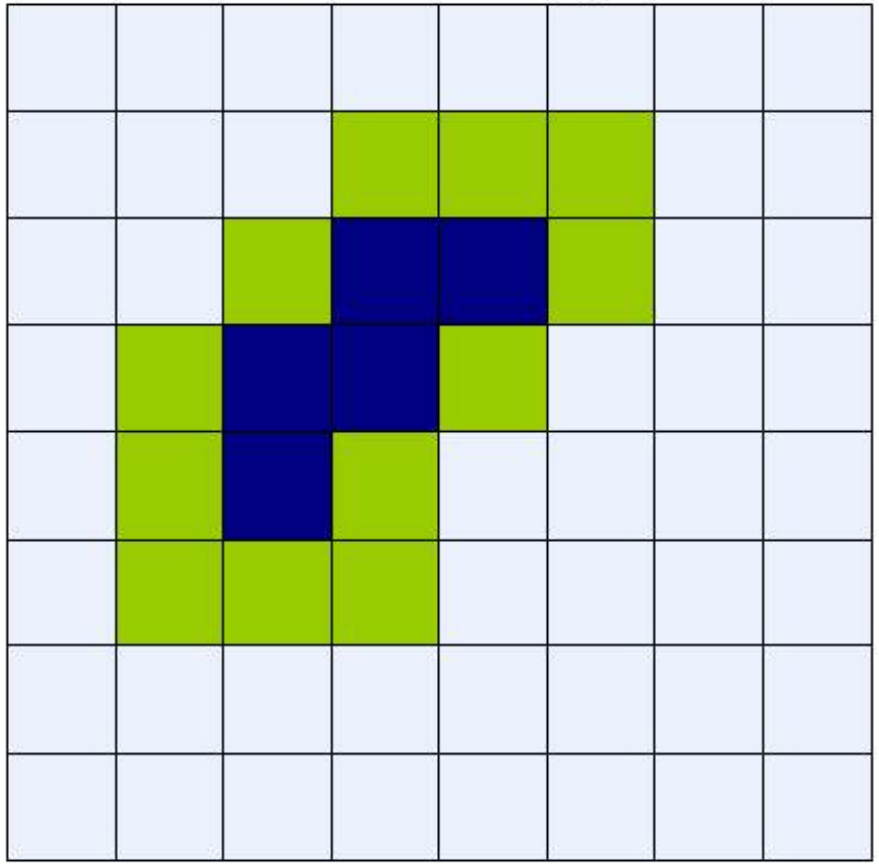


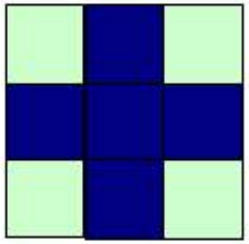
Erosion Example

Original Image



Processed Image





Structuring Element

Erosion Example 1

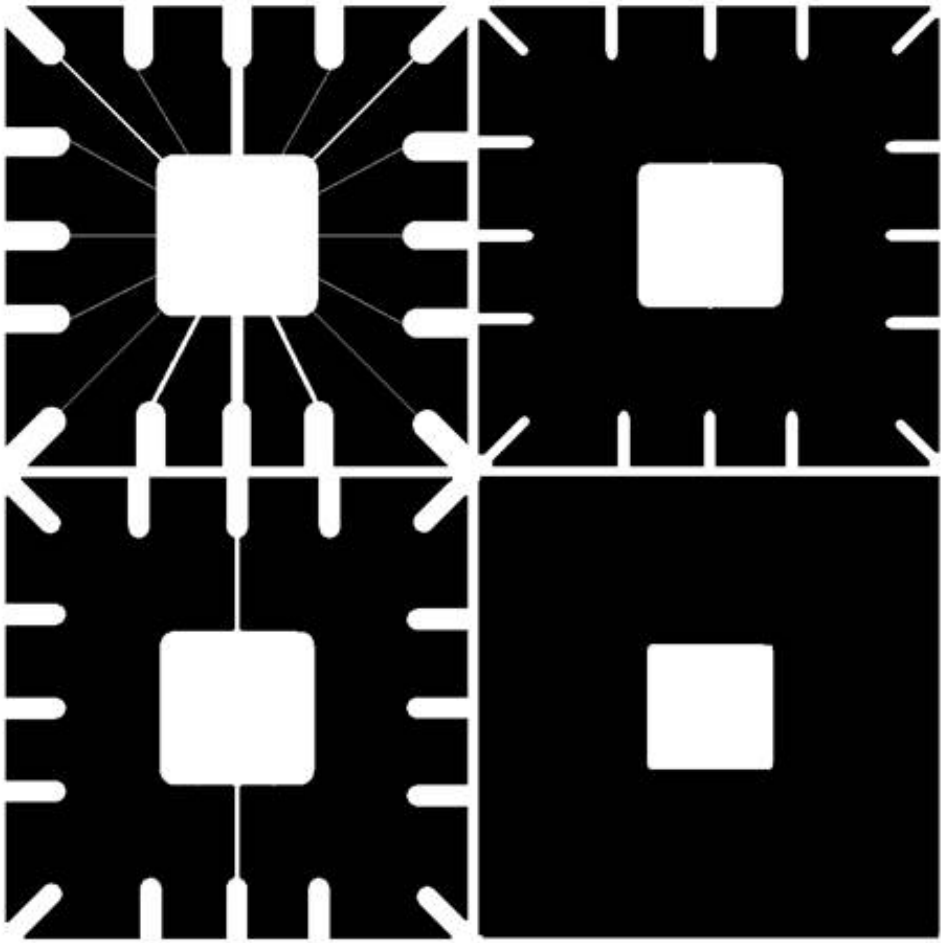
Original image

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!

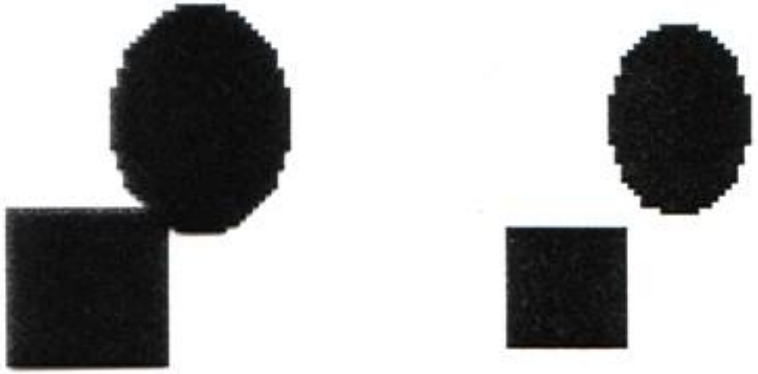
Erosion Example 2



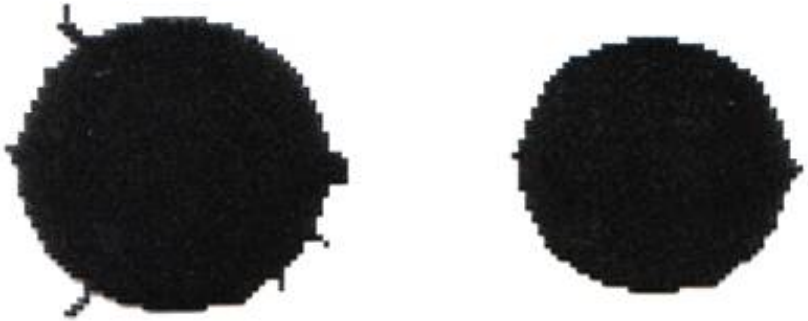
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What Is Erosion For?

Erosion can split apart joined objects



Erosion can strip away protrusions



Watch out: Erosion shrinks objects

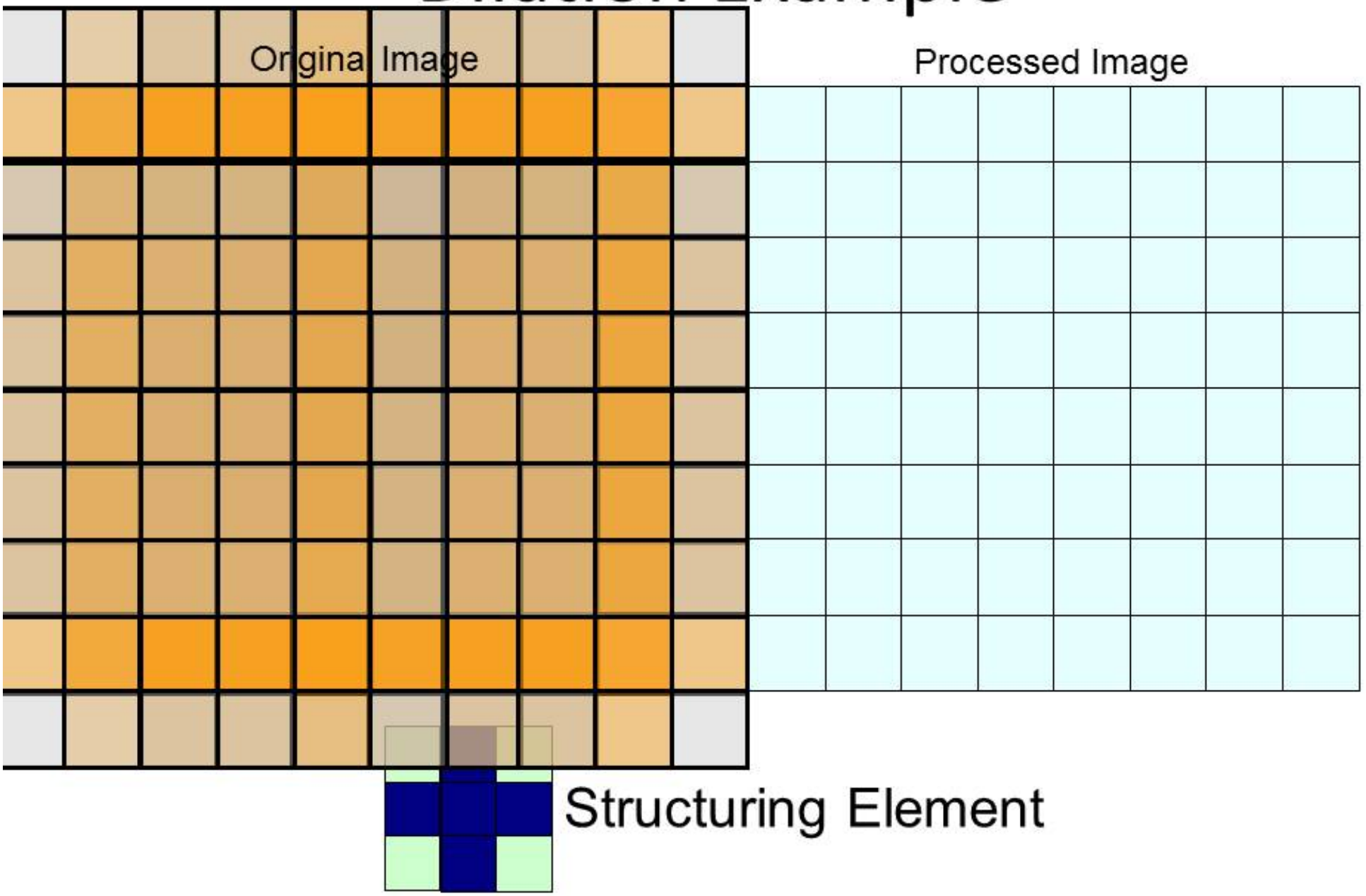
Dilation

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

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

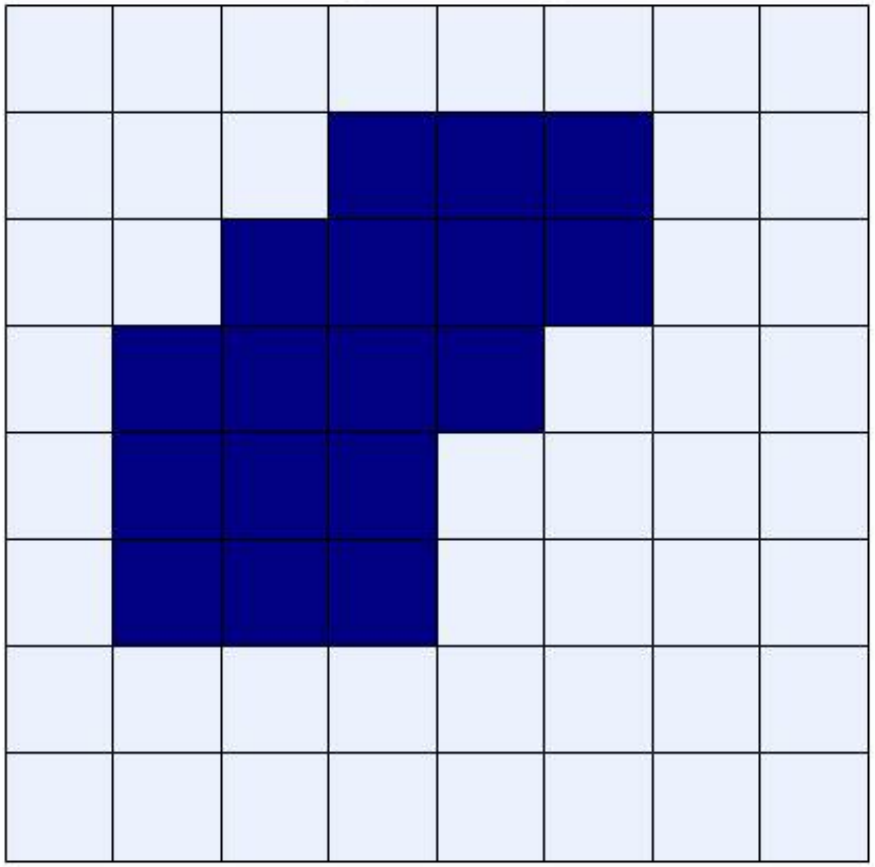
$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ hits } f \\ 0 \text{ otherwise} \end{cases}$$

Dilation Example

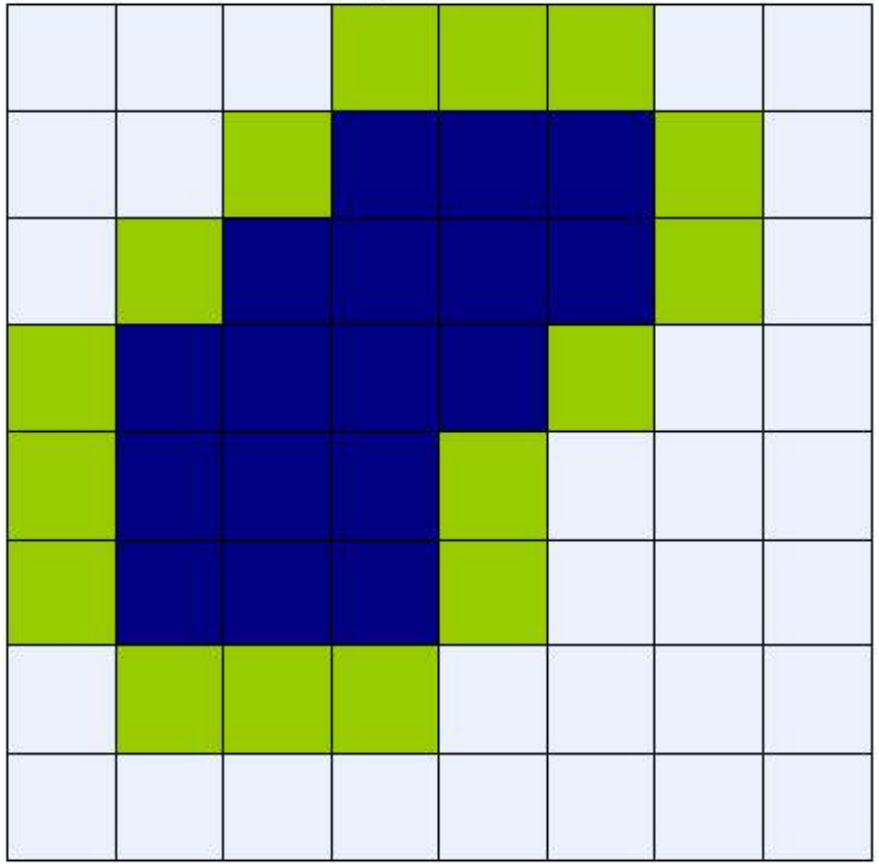


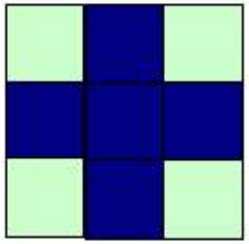
Dilation Example

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

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

Dilation Example 2

Original image

After dilation

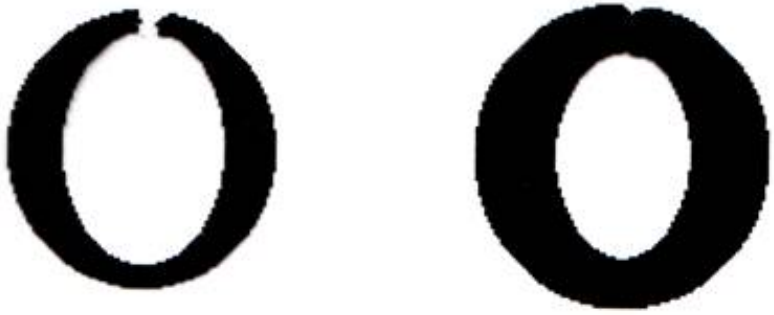
0	1	0
1	1	1
0	1	0

Structuring element

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

What Is Dilation For?

Dilation can repair breaks



Dilation can repair intrusions

Watch out: Dilation enlarges objects

Compound Operations

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

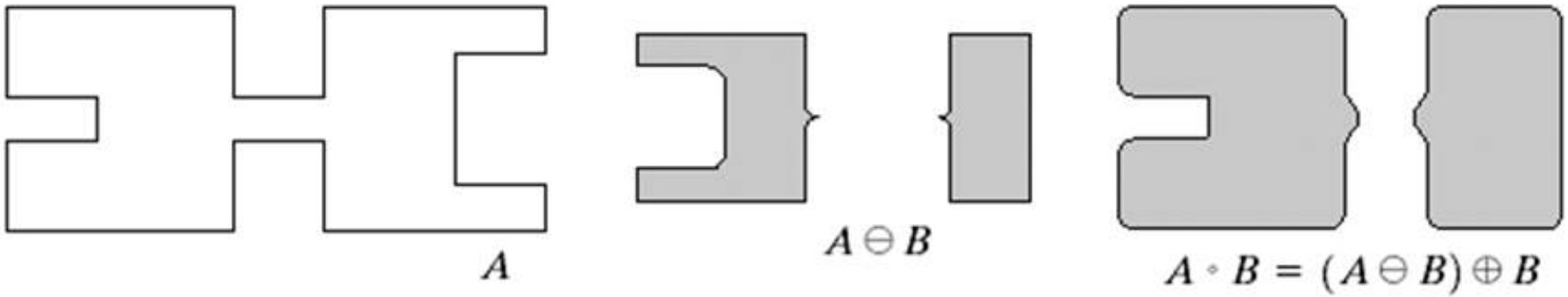
The most widely used of these *compound operations* are:

- Opening
- Closing

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)

Opening Example

Original Image

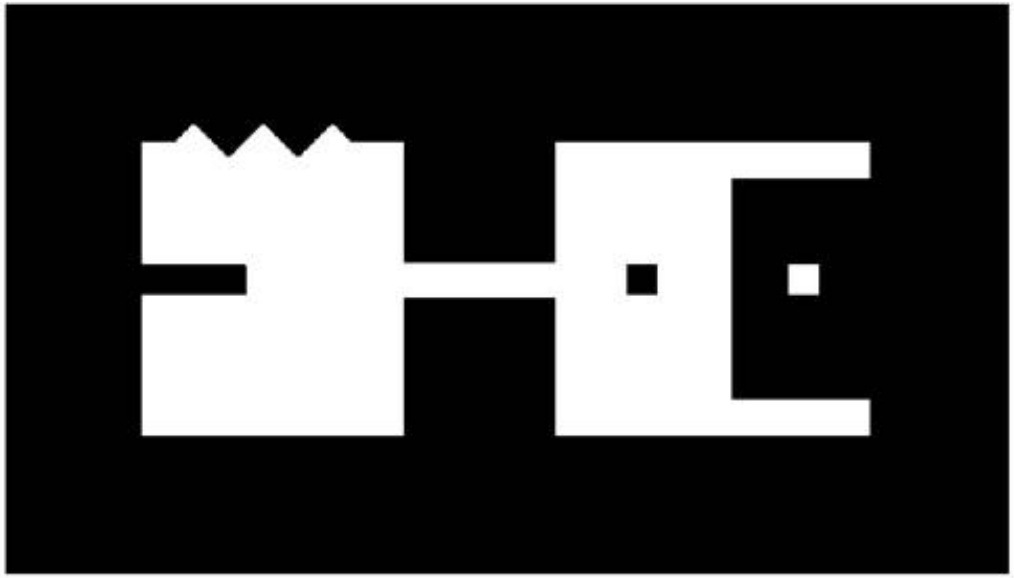
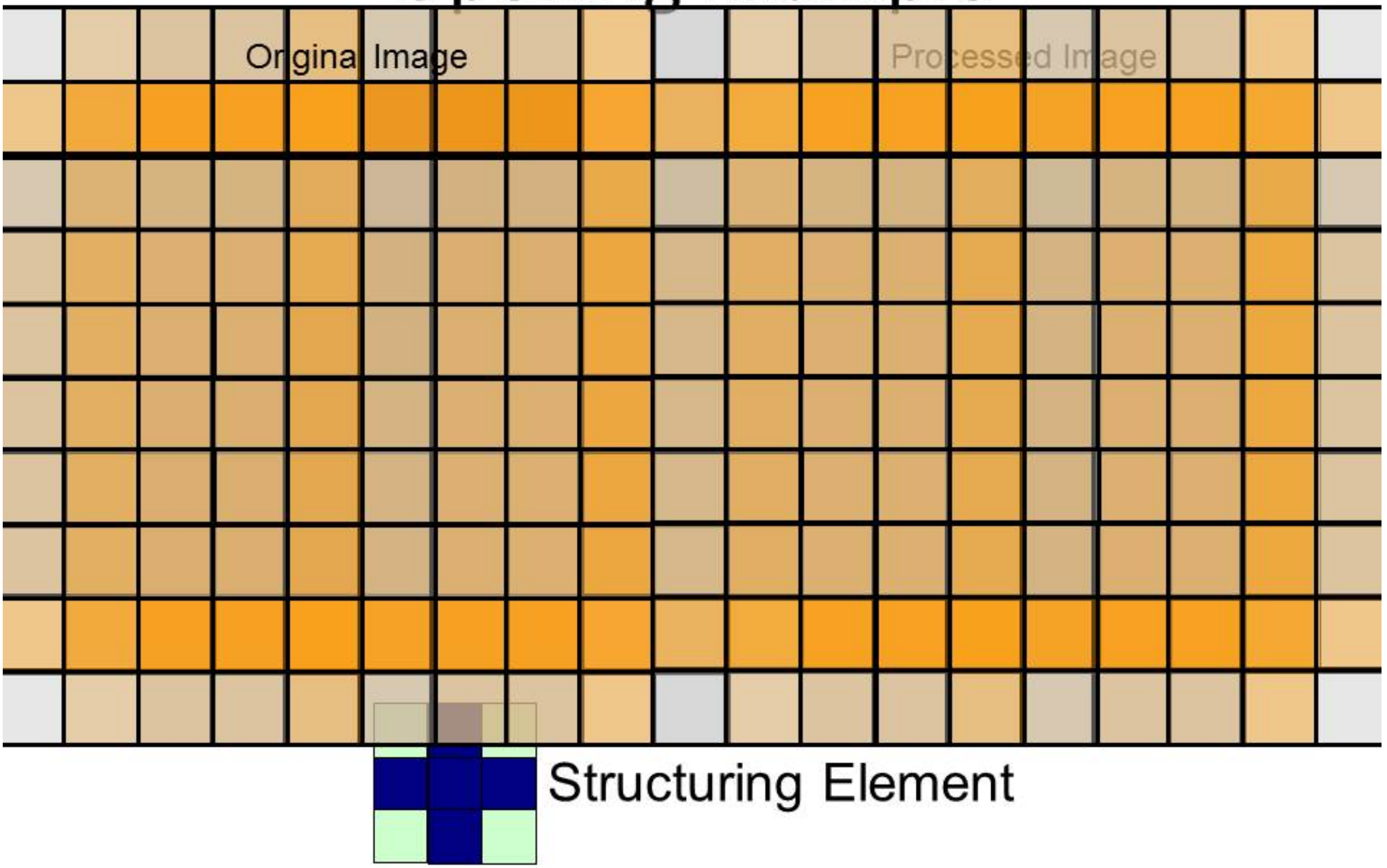


Image After Opening

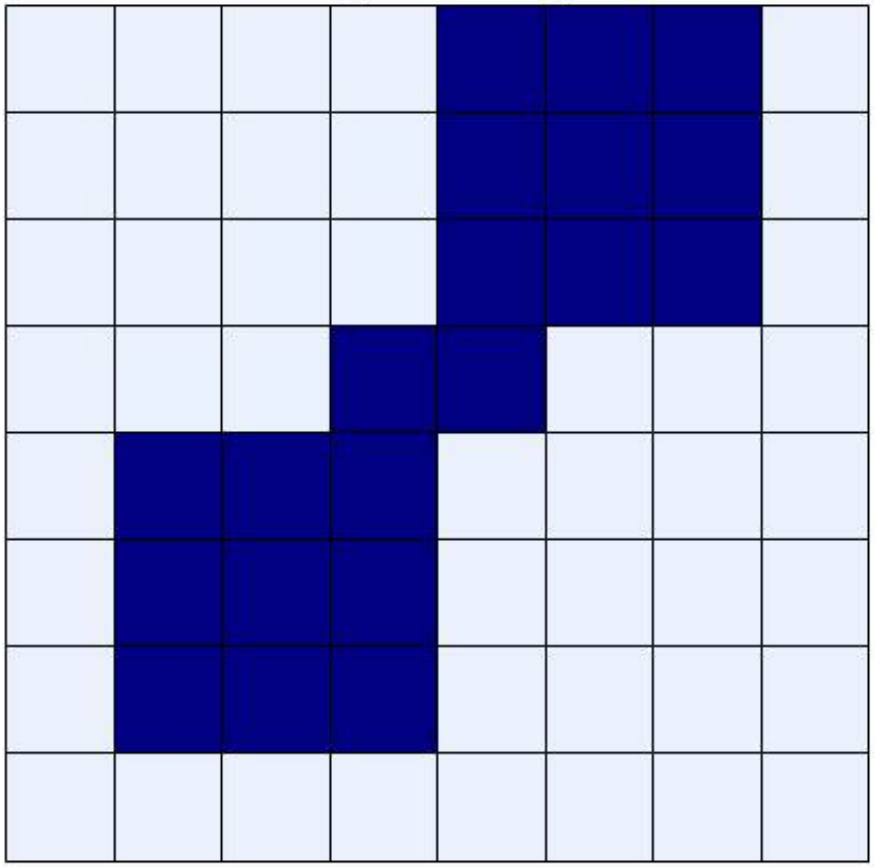
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Opening Example

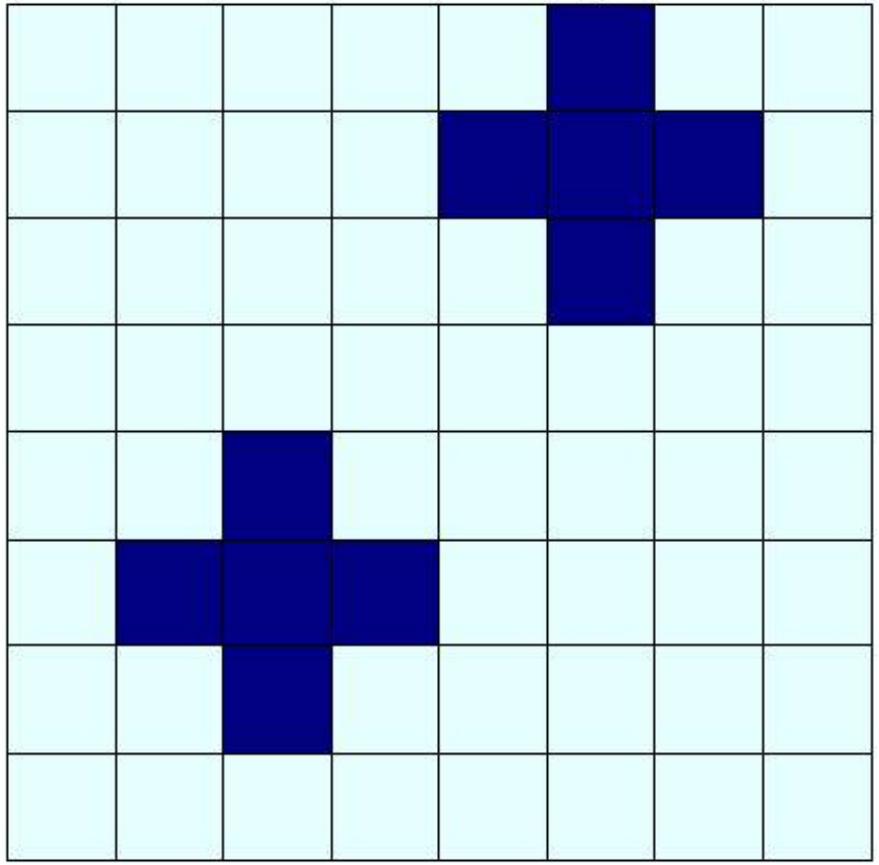


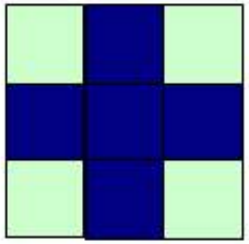
Opening Example

Original Image



Processed Image



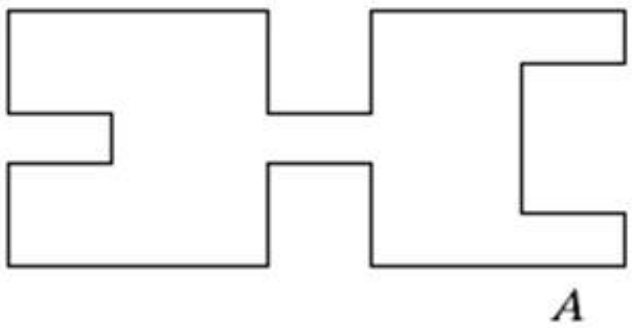


Structuring Element

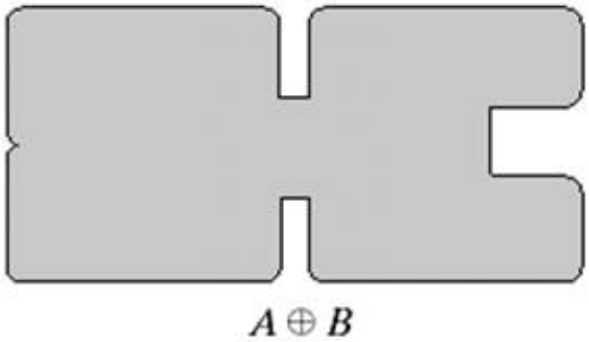
Closing

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

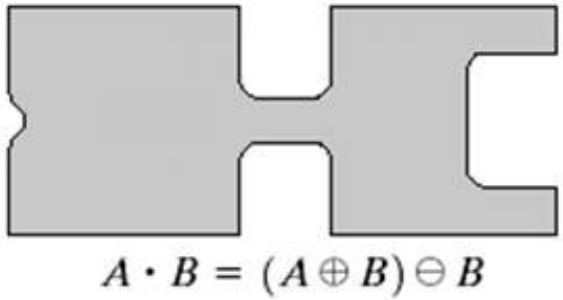
$$f \bullet s = (f \oplus s) \ominus s$$



Original shape



After dilation

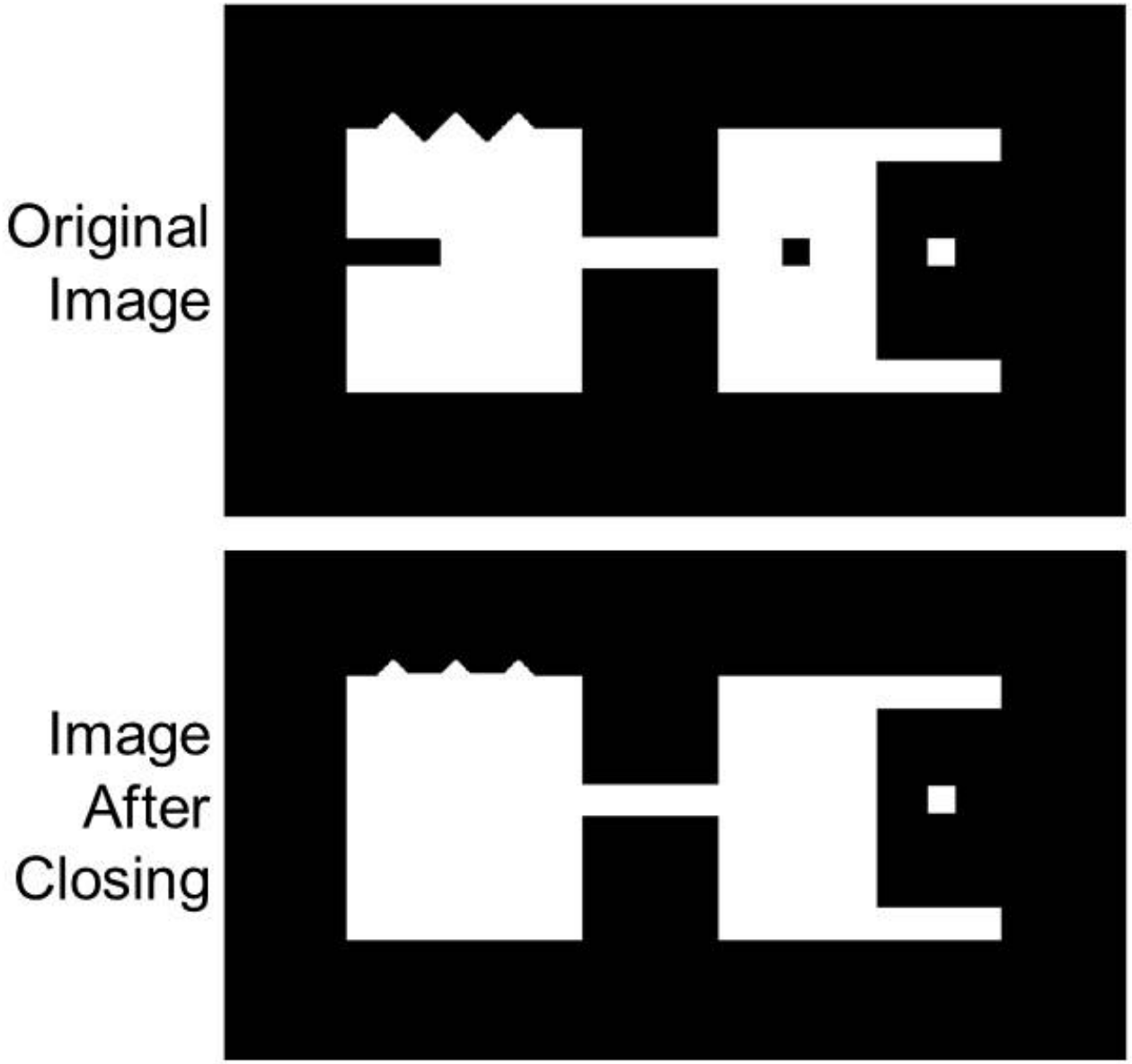


After erosion (closing)

Note a disc shaped structuring element is used

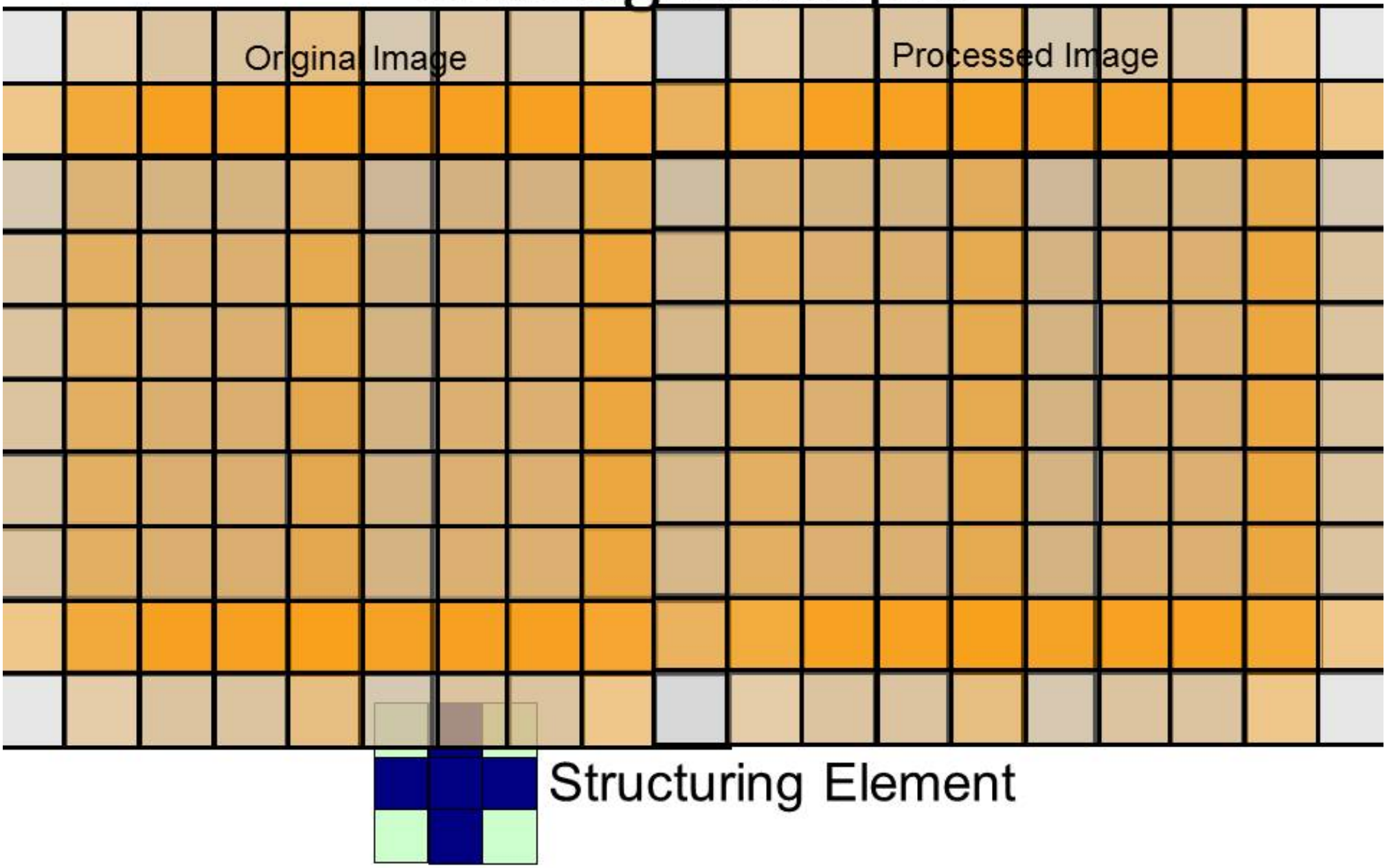
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Closing Example



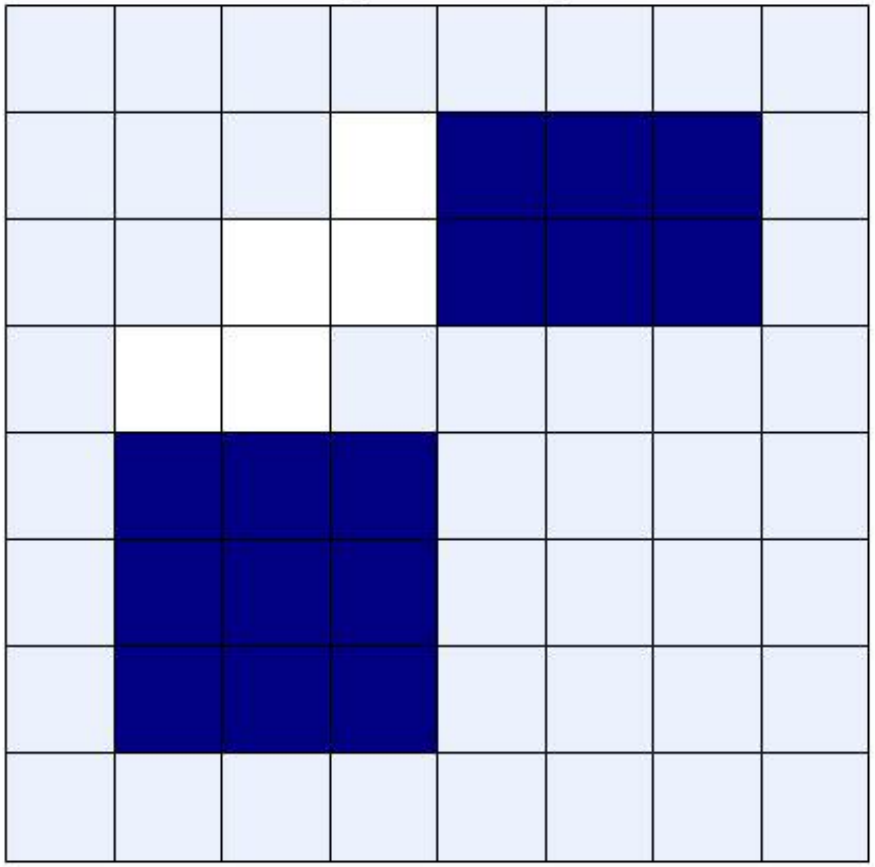
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Closing Example

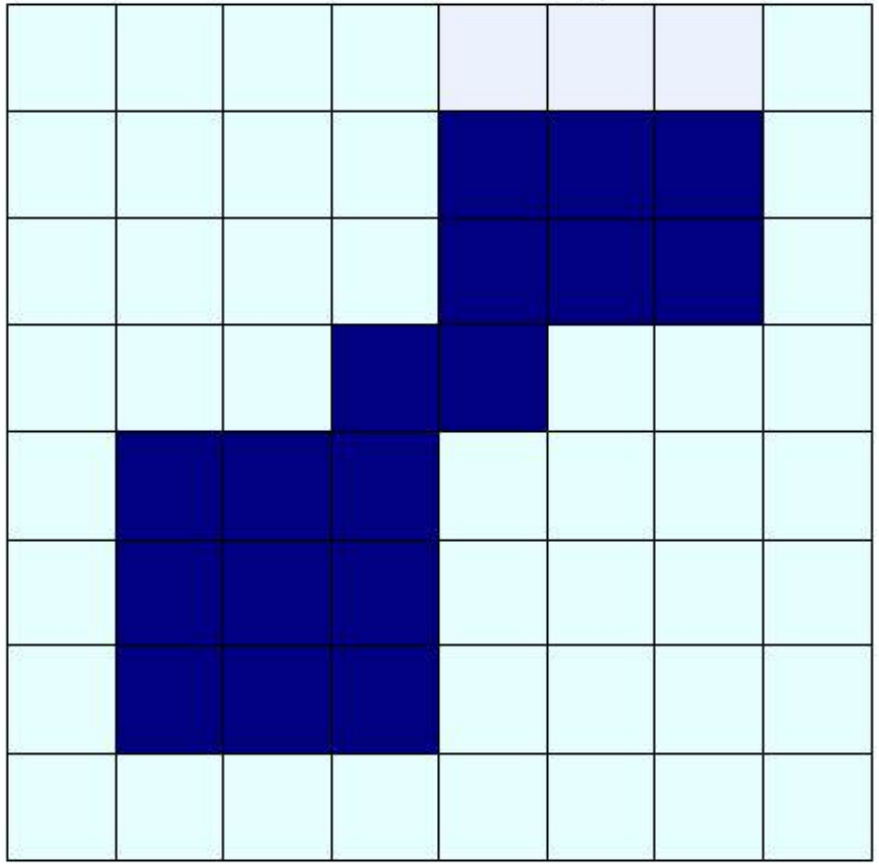


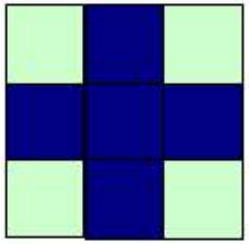
Closing Example

Original Image



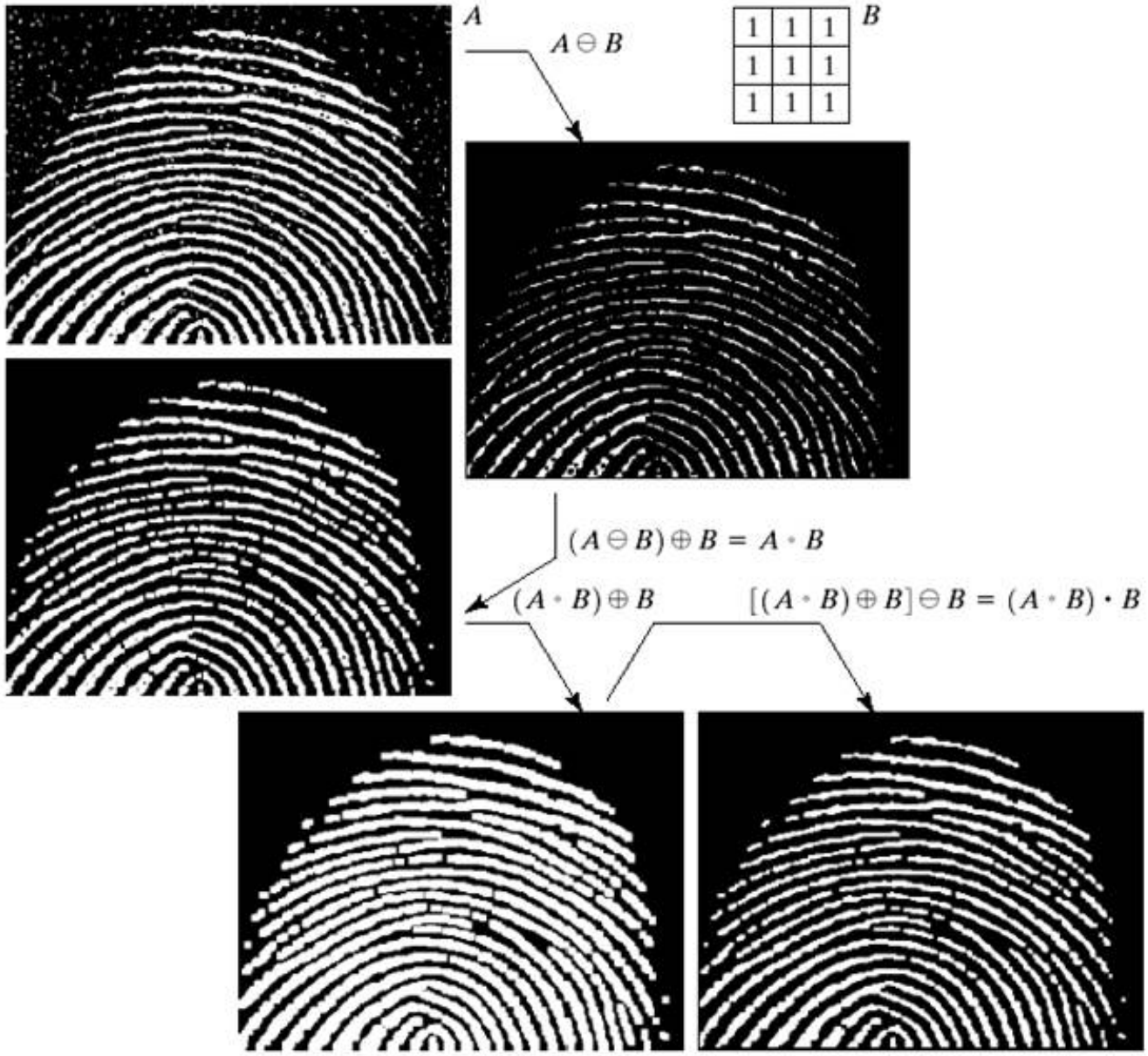
Processed Image





Structuring Element

Morphological Processing Example



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

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

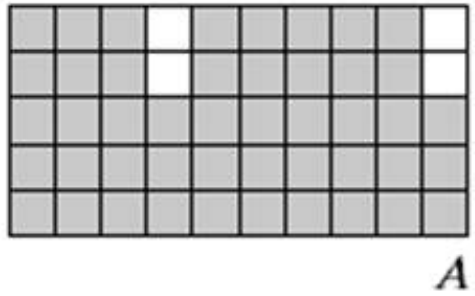
Boundary Extraction

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

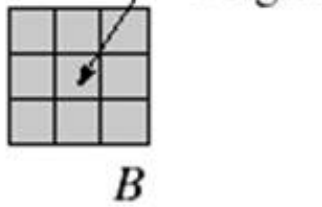
Extracting the boundary (or outline) of an object is often extremely useful

The boundary can be given simply as

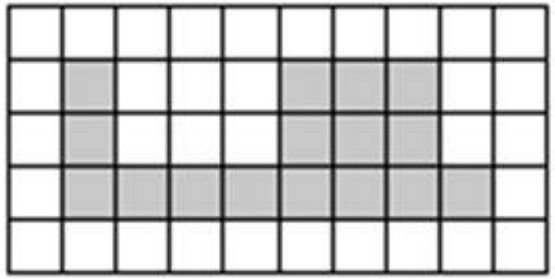
$$\beta(A) = A - (A \ominus B)$$



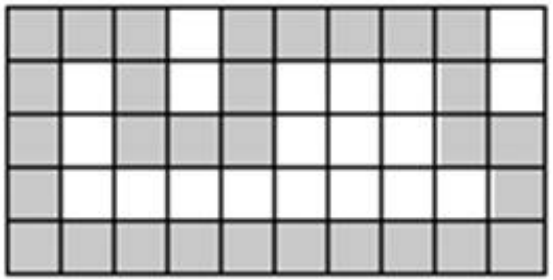
A



B



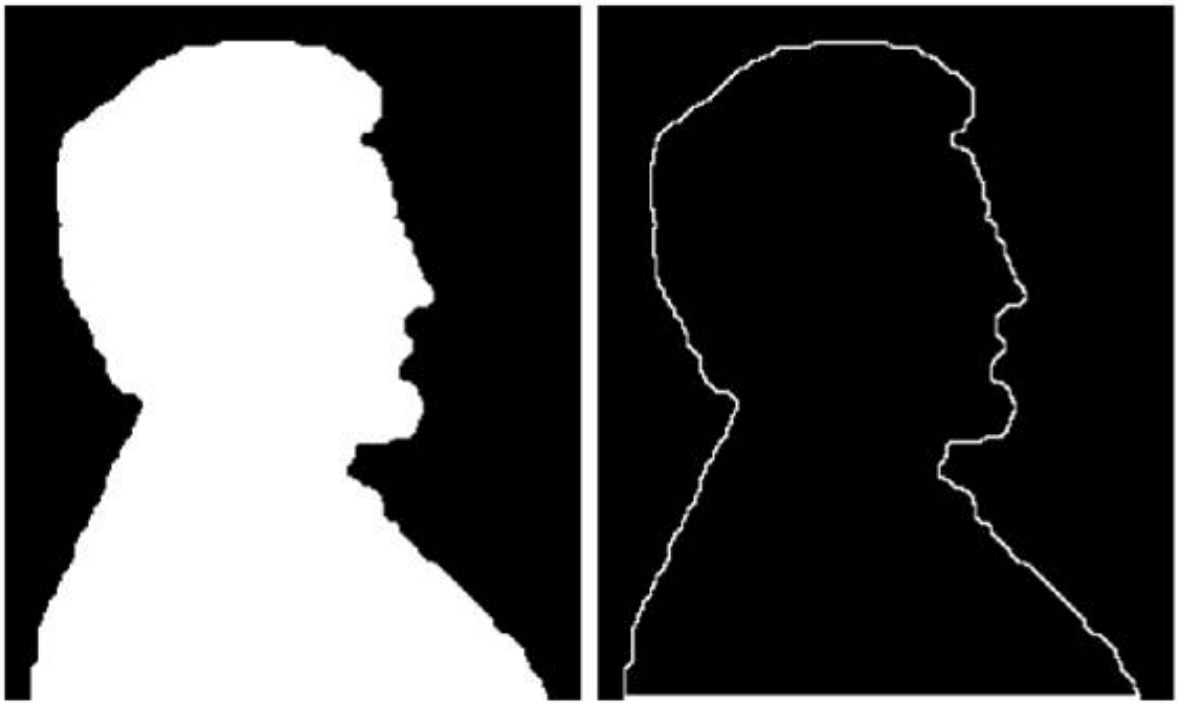
$A \ominus B$



$\beta(A)$

Boundary Extraction Example

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

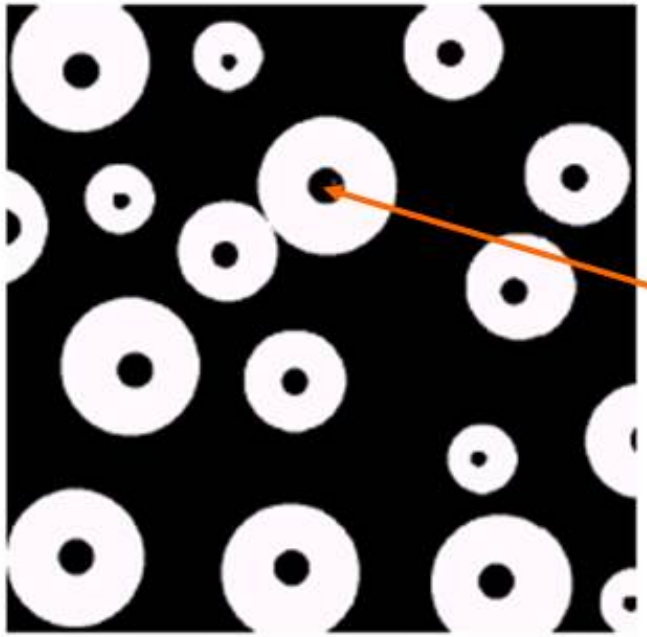


Original Image Extracted Boundary

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

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)

Region Filling (cont…)

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

The key equation for region filling is

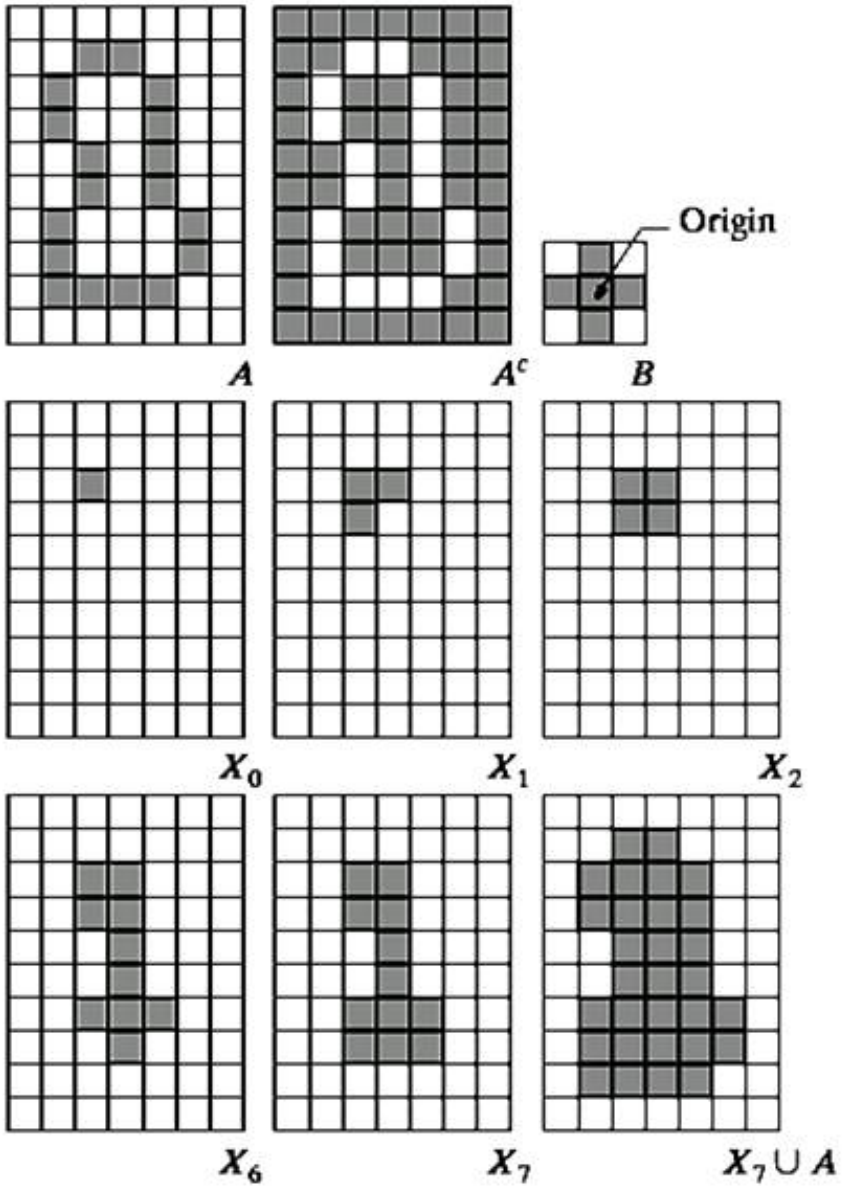
$$X_k = (X_{k-1} \oplus B) \cap A^c \qquad k = 1,2,3.....$$

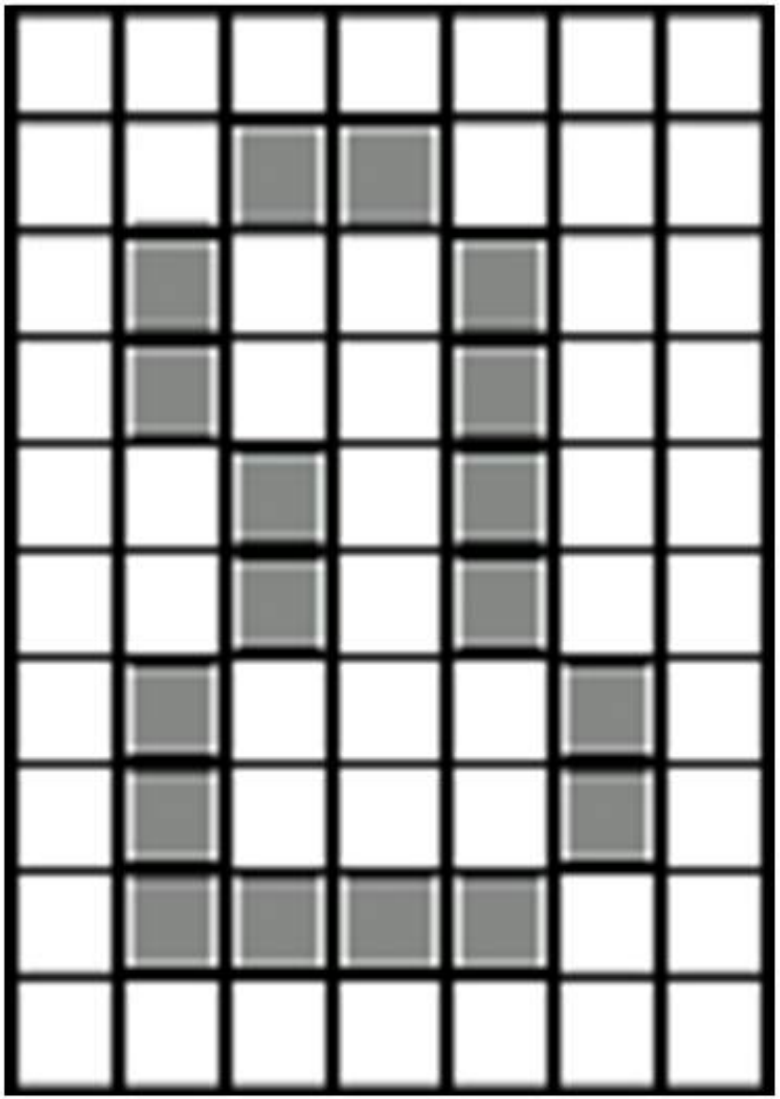
Where X_0 is simply the starting point inside the boundary, B is a simple structuring element and A^c is the complement of A

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

Finally the result is unioned with the original boundary

Region Filling Step By Step





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

Region Filling Example

Original Image

One Region Filled

All Regions Filled

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

Summary

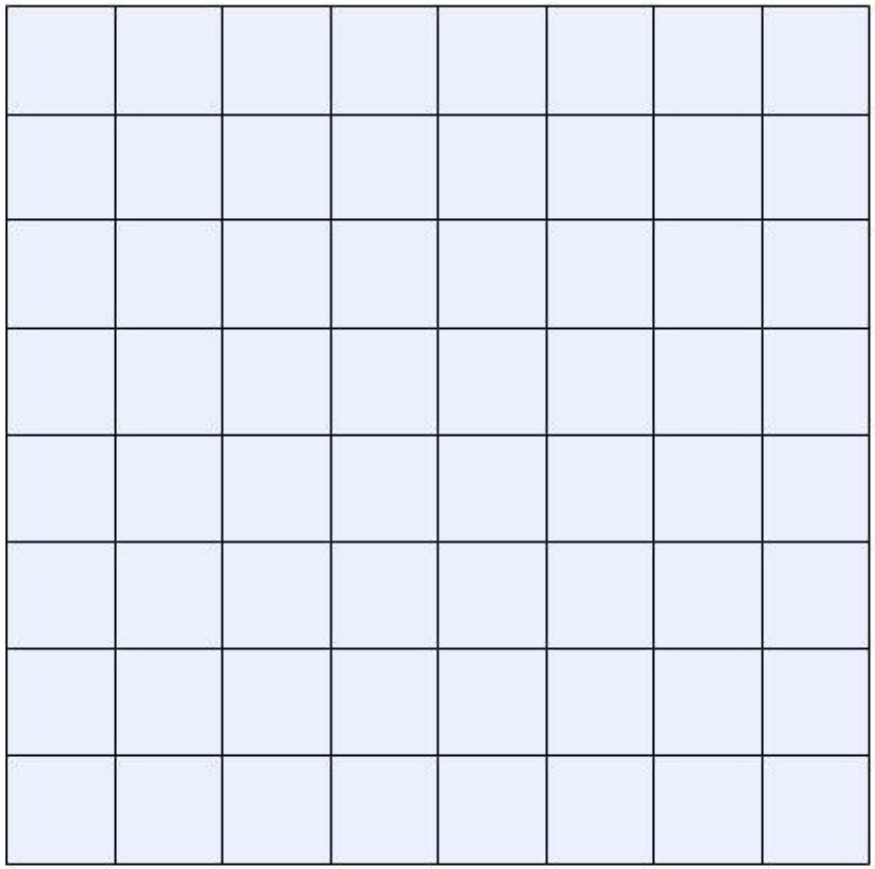
The purpose of morphological processing is primarily to remove imperfections added during segmentation

The basic operations are *erosion* and *dilation*

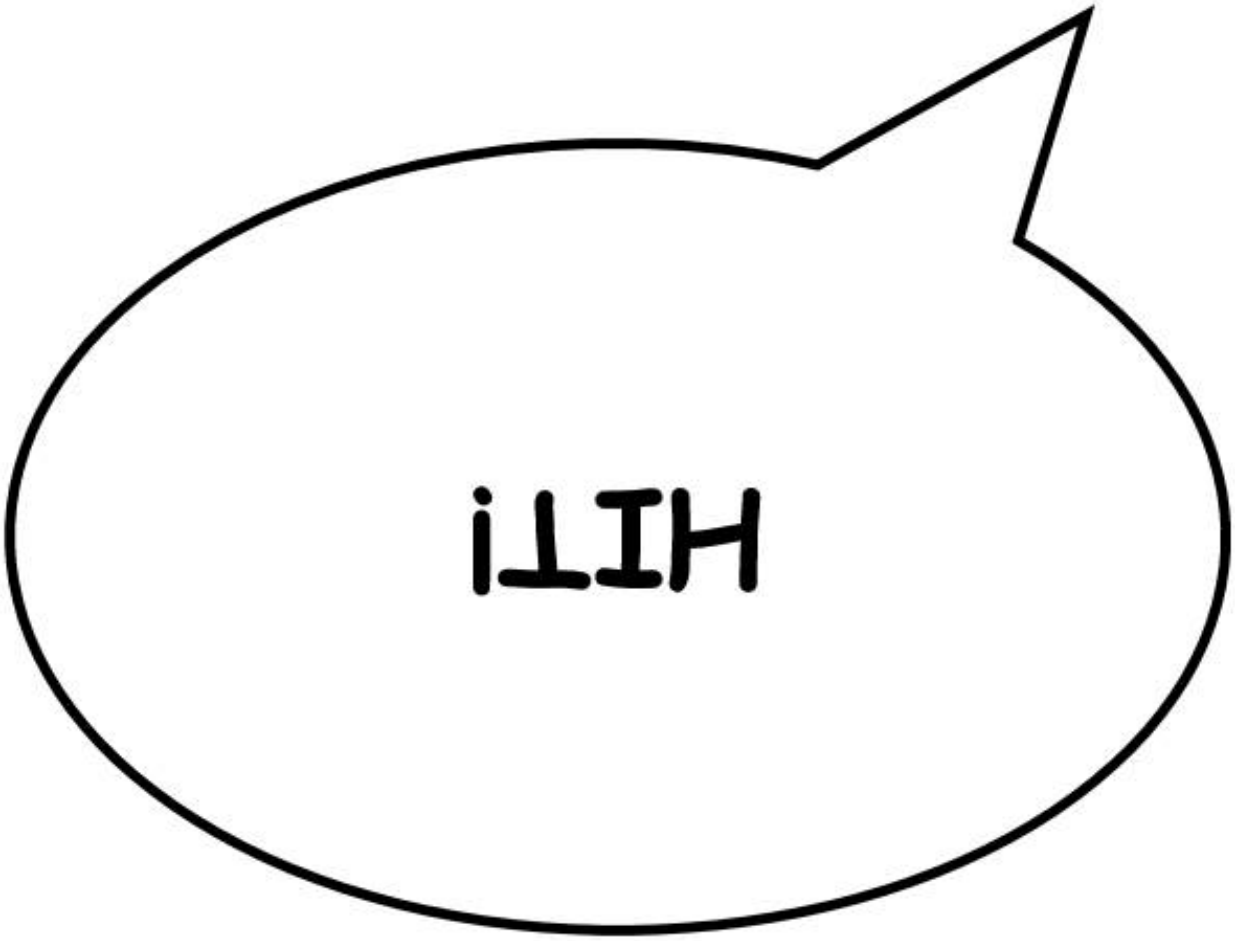
Using the basic operations we can perform *opening* and *closing*

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

Structuring Elements, Hits & Fits



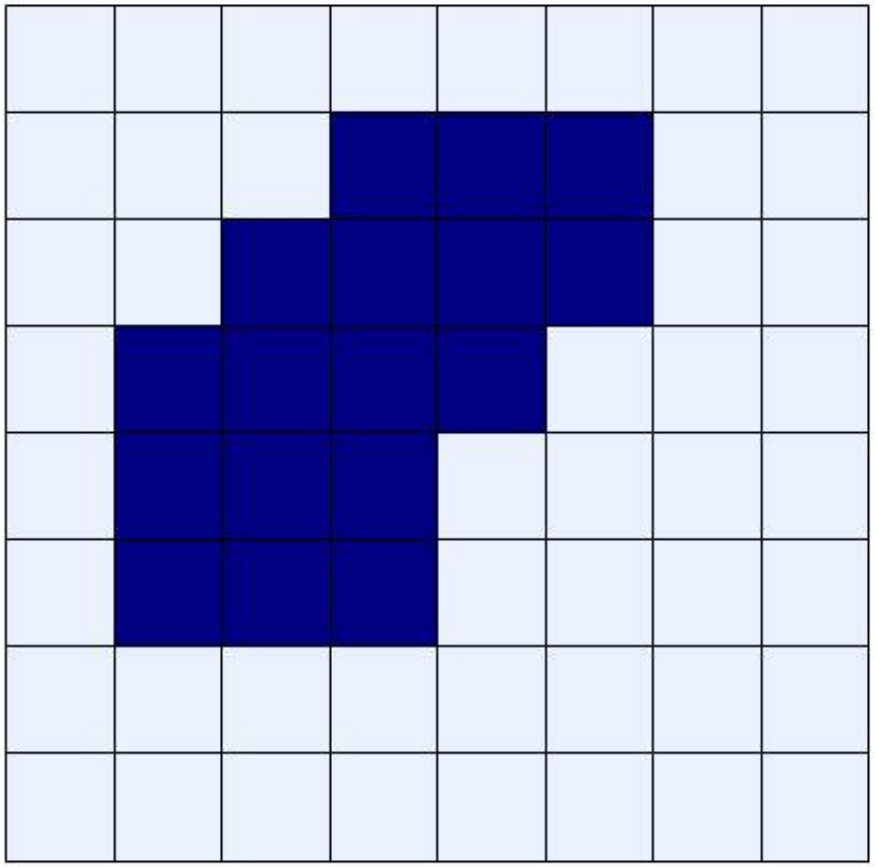
FIT!

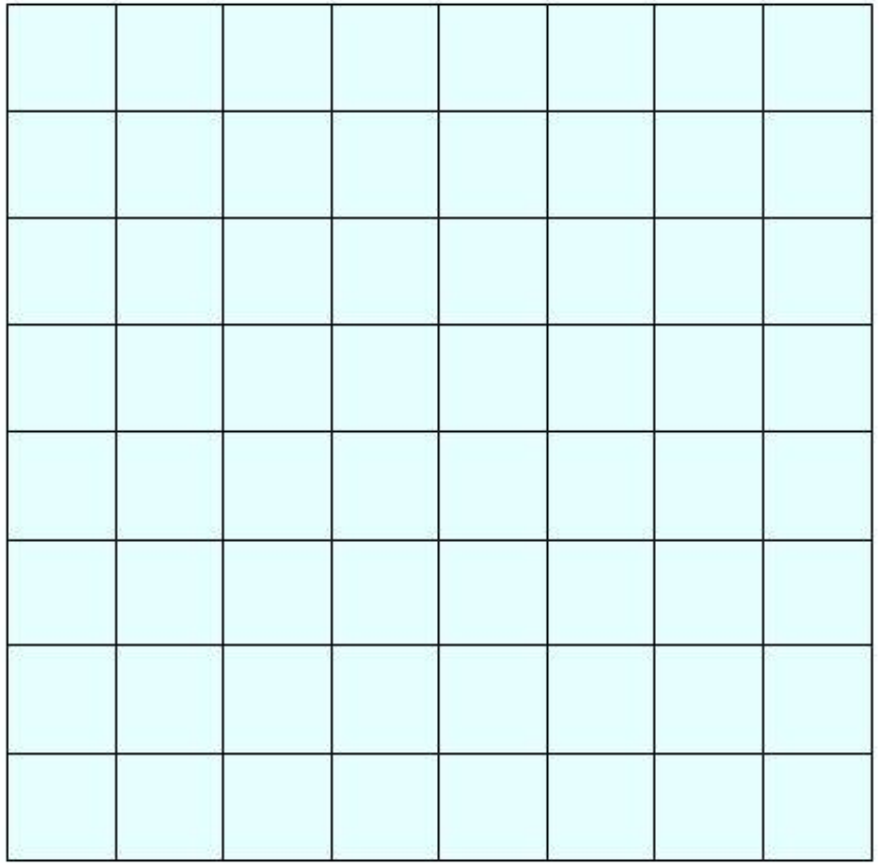

¡TIH

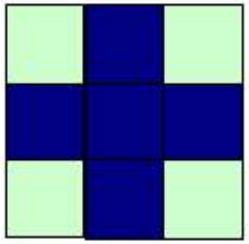
MISS!

MISS!

Erosion Example

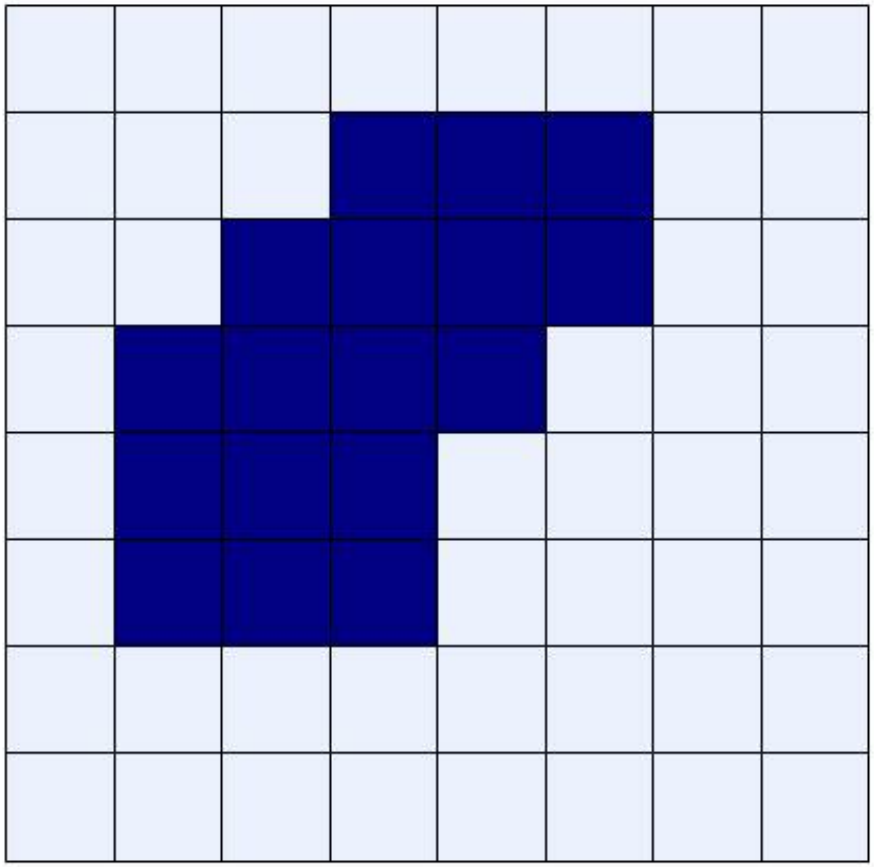


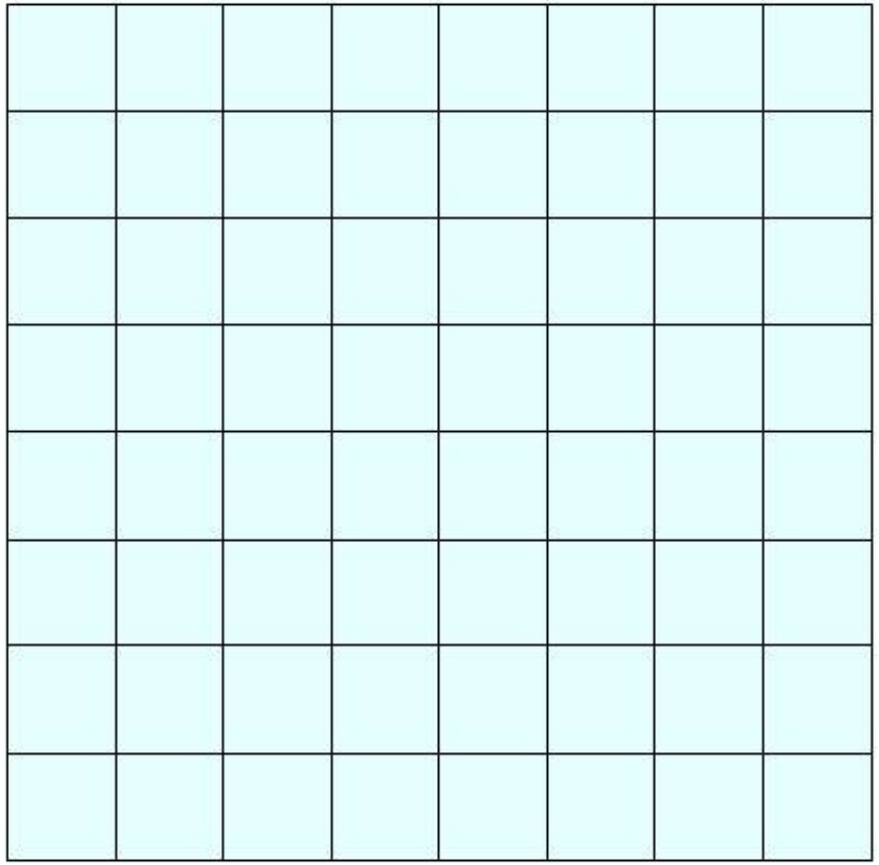


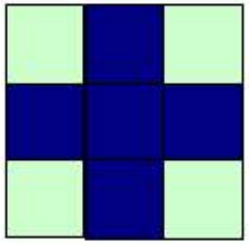


Structuring Element

Dilation Example



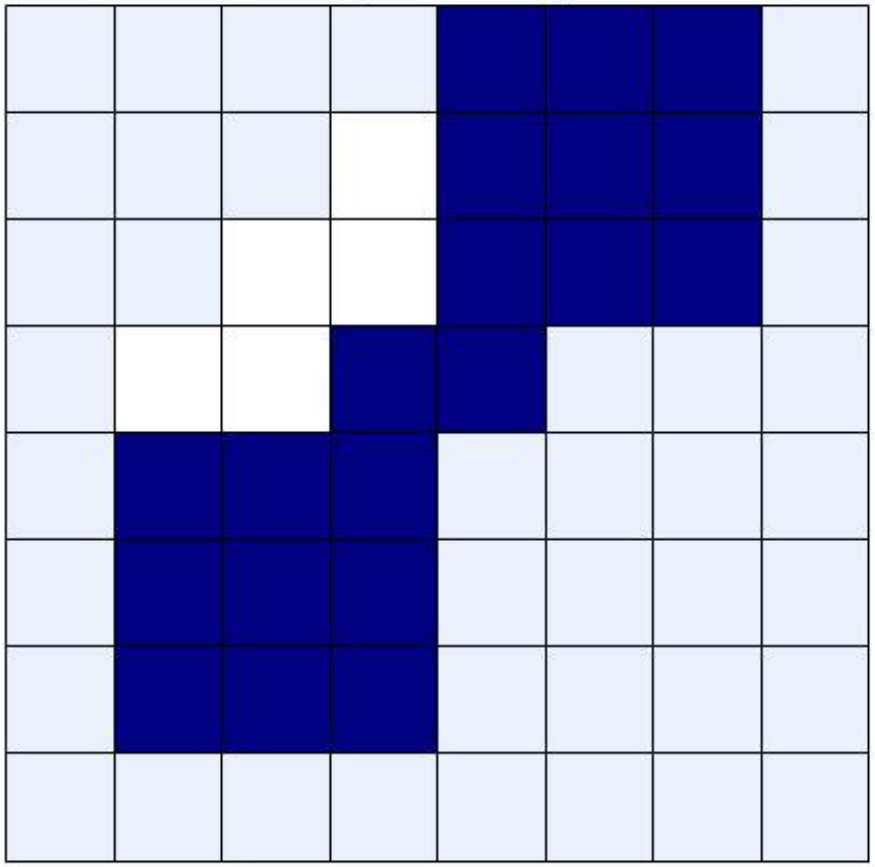




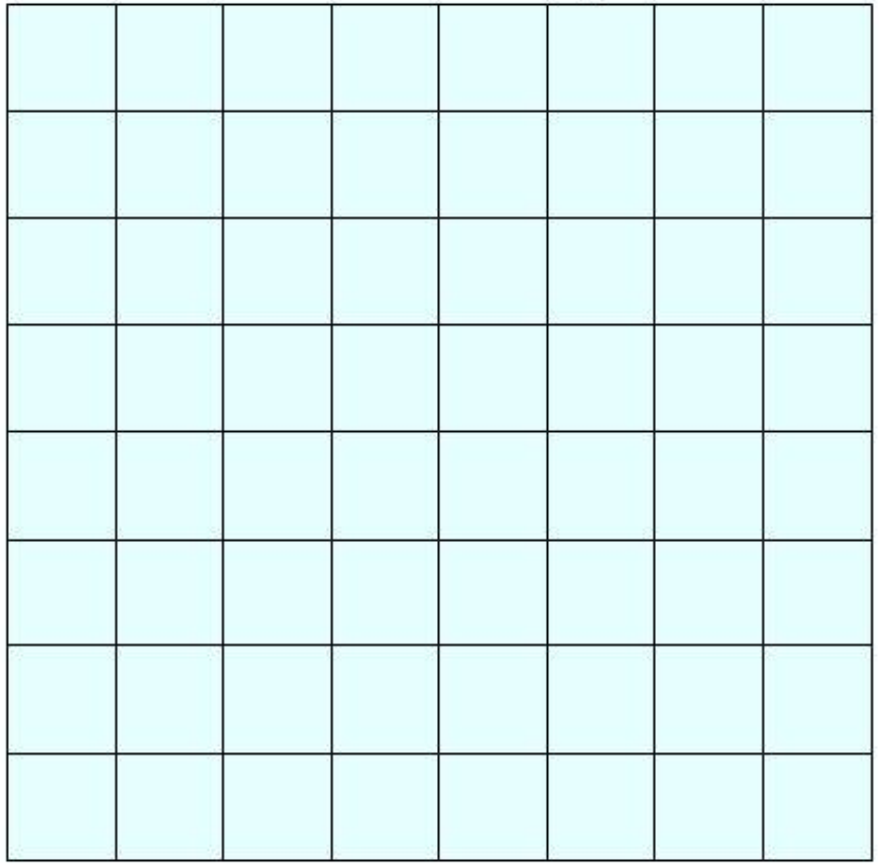
Structuring Element

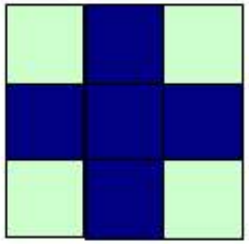
Opening Example

Original Image



Processed Image

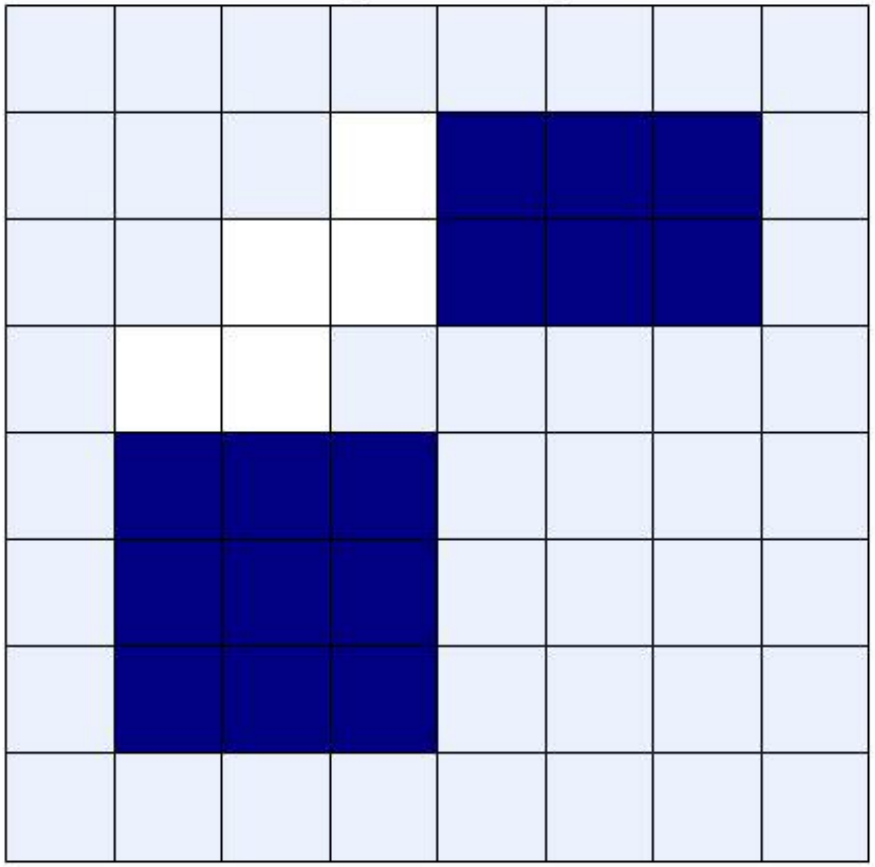




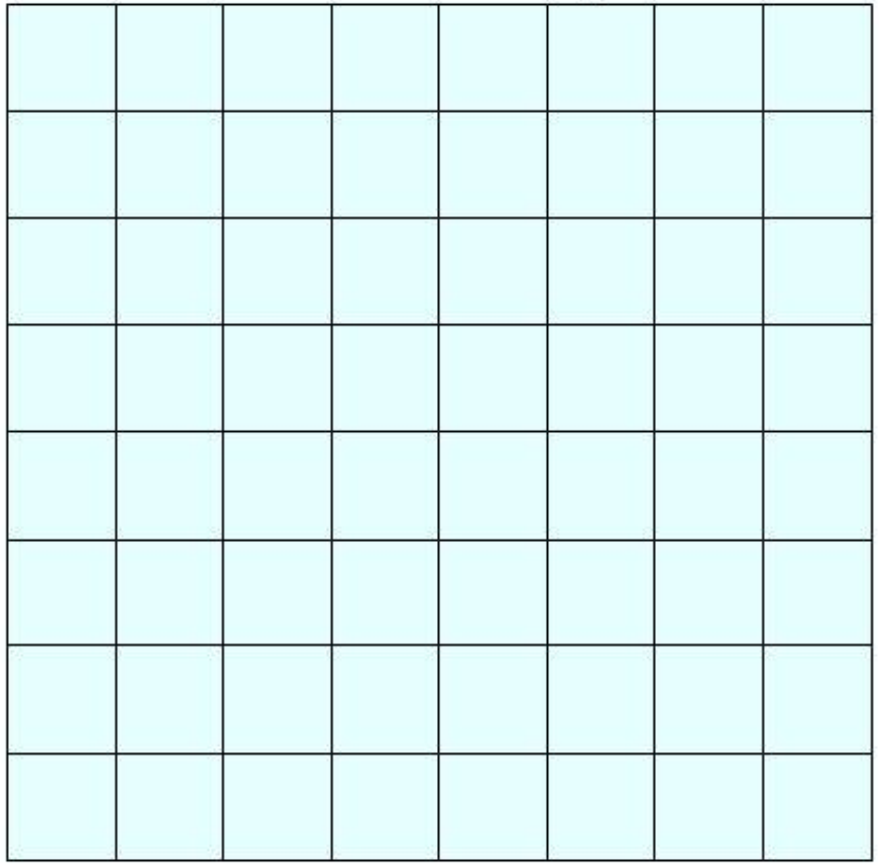
Structuring Element

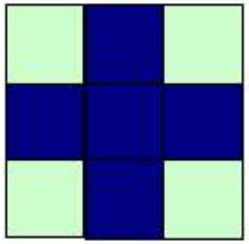
Closing Example

Original Image



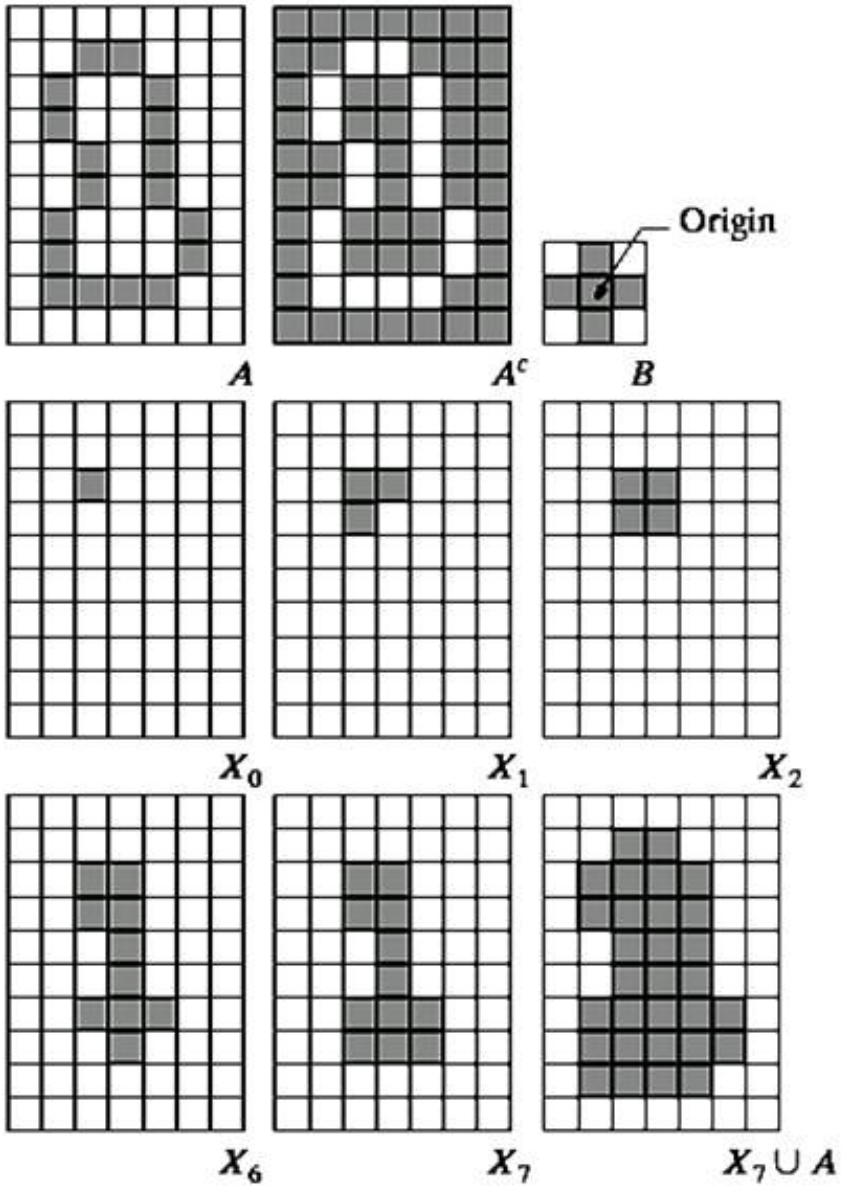
Processed Image

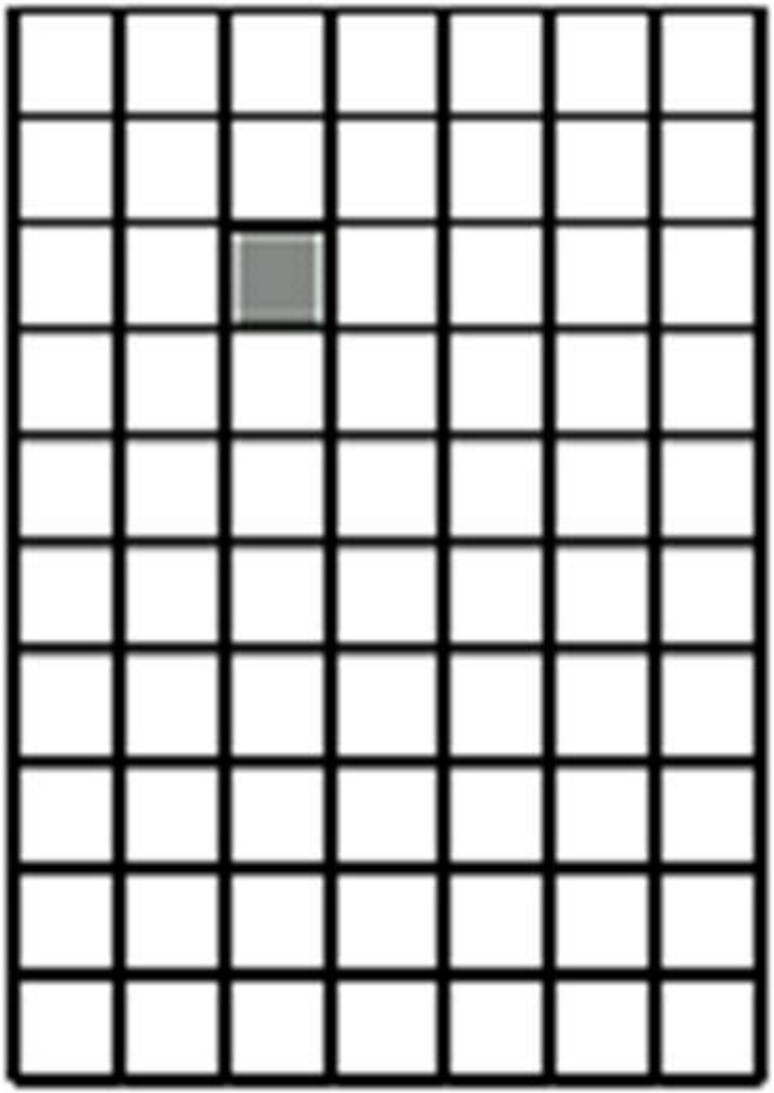




Structuring Element

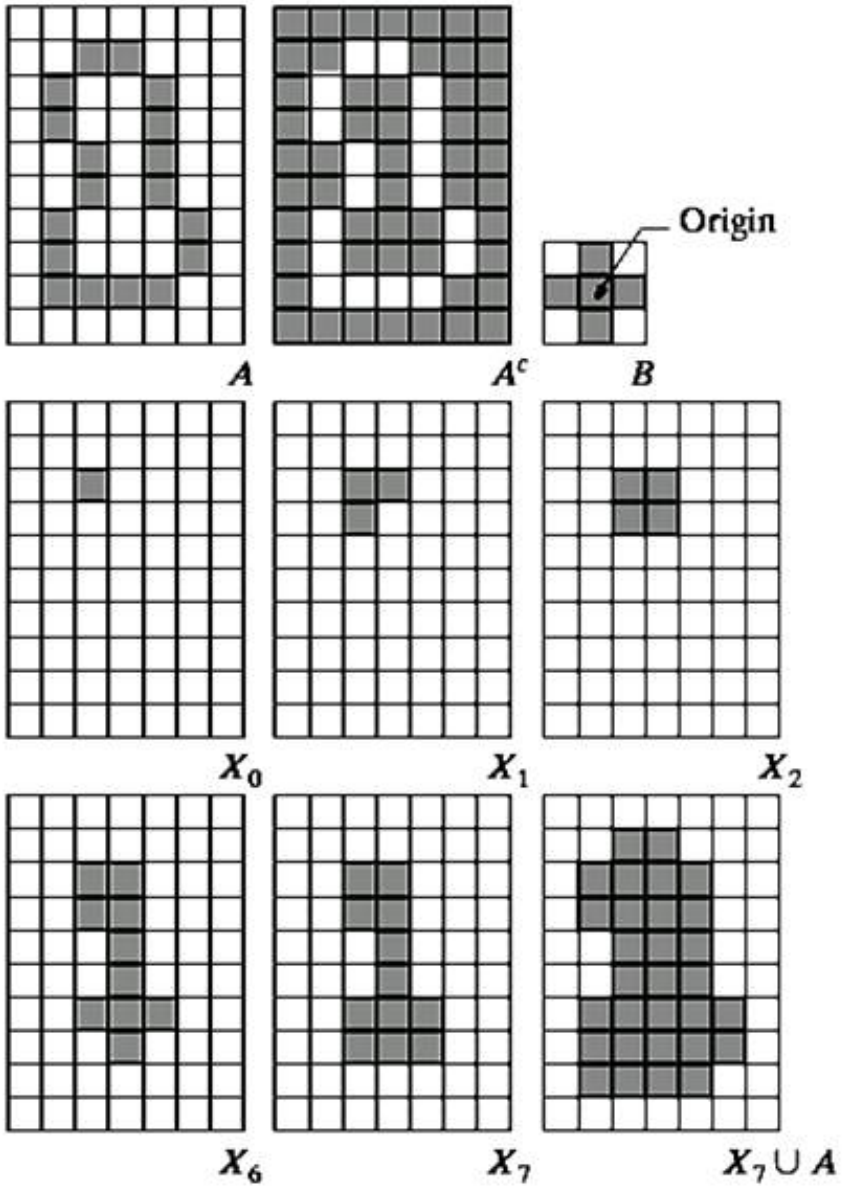
Region Filling Step By Step

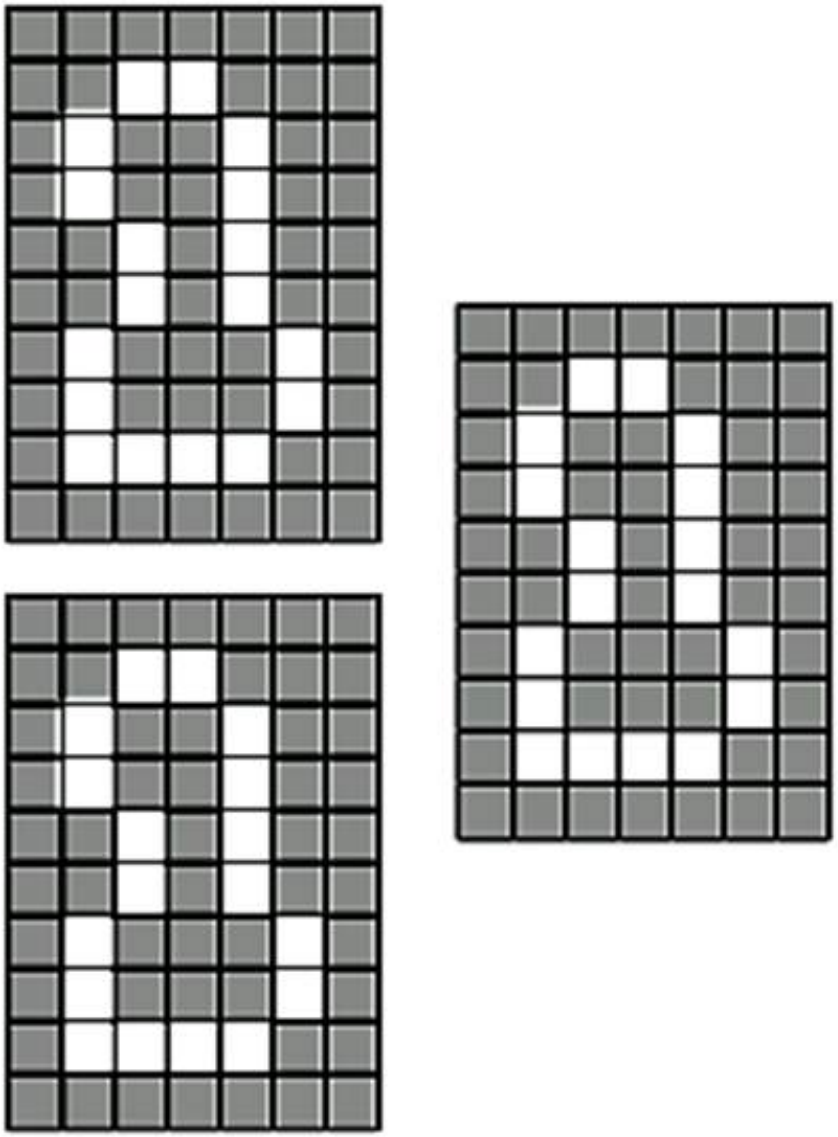




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Region Filling Step By Step





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