Lecture 7
Morphological Image Processing

Hongyu Li
School of Software Engineering
Tongji University
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

Structuring Elements, Hits & Fits

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
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

Original Image

Processed Image With Eroded Pixels

Structuring Element
Erosion Example

Original Image

Processed Image

Structuring Element
Erosion Example 1

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

What Is Erosion For?

Erosion can split apart joined objects

Erosion can strip away extrusions

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

Original Image

Processed Image

Structuring Element
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!
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.

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

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

Note a disc shaped structuring element is used.
Opening Example

Original Image

Image After Opening

Opening Example

Original Image

Processed Image

Structuring Element
Opening Example

Original Image

Processed Image

Structuring Element
Opening Example

Original Image

Processed Image

Structuring Element
Opening Example

Original Image

Processed Image

Structuring Element
Closing

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

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

Note a disc shaped structuring element is used
Closing Example

Original Image

Image After Closing

## Closing Example

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Processed Image</th>
</tr>
</thead>
</table>

### Structuring Element

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Closing Example

Original Image

Processed Image

Structuring Element
Morphological Processing Example

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

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 3*3 structuring element

Region Filling

Given a pixel inside a boundary, \textit{region filling} attempts to fill that boundary with object pixels (1s)

Region Filling (cont…) 

The key equation for region filling is

\[ X_k = (X_{k-1} \oplus B) \cap A^c \quad k = 1,2,3,\ldots \]

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

Region Filling Example

Original Image
One Region Filled
All Regions Filled

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 operations can then be implemented using combinations of all these.
Thanks for your attention