SINDH MADRESSATUL ISLAM UNIVERSITY
Aiwan-e-Tijarat Rd, Seari Quarters, Karachi, Karachi City,
Sindh 74000, Pakistan.

Table of Contents

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Morphological Image Processing

Abstract:

The approach of morphological operations is simplistic and is based on set theory. The goal of applying morphological operations is to improve the image's structure by eliminating defects. The majority of the operations performed here combine the two processes of erosion and dilatation. A small matrix structure known as a structuring element is used in the technique. The final outcome is substantially determined by the size and shape of the structuring element. The basic morphological techniques are used on some common photos in this paper in an effort to better comprehend them. The tool for experimenting with morphological procedures is the MATLAB software.

Keywords: Mathematical morphology, Black pixel, Object Recognition, Image enhancement, Feature extraction.

Introduction:

Morphological image processing is a technique used to process digital images by applying mathematical operations to the pixels in the image. These operations are based on the shape or structure of the image, and are used to extract features or detect patterns in the image. There are several basic morphological operations. Each of these operations performs a specific type of image transformation, and they can be combined in various ways to achieve a wide range of image processing tasks. Some examples of the types of tasks that can be achieved using morphological image processing include removing noise or small, isolated features from an image, filling in gaps or holes, extracting and labeling connected components, and enhancing or smoothing the boundaries of objects in an image. Overall, morphological image processing is a powerful and flexible technique that is widely used in a variety of applications, including computer vision, medical imaging, and remote sensing.

Morphological Operations:

Some common morphological operations are following.

1. **Erosion.**
2. **Dilation.**
3. **Opening.**
4. **Closing.**

These operations can be used to remove noise, smooth edges, or identify objects in an image.

Operations With Mathematics:

Erosion:

Erosion is an operation that involves sliding a kernel over an image and setting the value of each pixel in the output image to the minimum value within the kernel. This operation can be used to thin or remove small structures in the image.

Here is an example of erosion using a 3x3 kernel:

Input image:
[1 0 1]
[0 1 0]
[1 0 1]

Kernel:
[1 1 1]
[1 1 1]
[1 1 1]

Output image:
[0 0 0]
[0 1 0]
[0 0 0]

The erosion of an image f with a structuring element s is defined as:

$$f \ominus s = \min\{f(x-a, y-b) \mid (a,b) \in s\}$$

where f(x,y) is the value of the pixel at position (x,y) in the image, s is the structuring element, and (a,b) is a position within the structuring element.

Dilation:

Morphological dilation is an image processing operation that is used to increase the size of certain features in an image. It works by taking an input image and a structuring element, and then "dilating" the image by applying the structuring element to each pixel in the image.

For example, suppose we have an input image that consists of a single black pixel on a white background. If we use a 3x3 square structuring element for dilation, the output image will be a 3x3 square of black pixels, with the original black pixel at the center:

Input image:
[255, 255, 255]
[255, 0, 255]
[255, 255, 255]

Structuring element:
[1, 1, 1]
[1, 1, 1]
[1, 1, 1]

Output image:
[0, 0, 0]
[0, 0, 0]
[0, 0, 0]

The dilation of an image f with a structuring element s is defined as:

$$f \oplus s = \max\{f(x-a, y-b) \mid (a,b) \in s\}$$

where f(x,y) is the value of the pixel at position (x,y) in the image, s is the structuring element, and (a,b) is a position within the structuring element.

Opening:

Morphological opening is an image processing operation that is used to remove small, isolated features from an image while preserving the overall structure of larger features. It works by first applying morphological erosion to an input image, and then applying dilation to the resulting image.

For example, suppose we have an input image that consists of a black square on a white background, with some small black pixels scattered around the image:

Input image:
[255, 255, 255, 255, 255]
[255, 0, 0, 0, 255]
[255, 0, 0, 0, 255]
[255, 0, 0, 0, 255]
[255, 255, 255, 255, 255]

If we apply morphological opening to this image using a 3x3 square structuring element, the resulting image will have the small, isolated black pixels removed, but the larger black square will be preserved:

Output image:
[255, 255, 255, 255, 255]
[255, 255, 255, 255, 255]
[255, 255, 0, 255, 255]
[255, 255, 255, 255, 255]
[255, 255, 255, 255, 255]

The opening of an image f with a structuring element s is defined as:

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

where f(x,y) is the value of the pixel at position (x,y) in the image, s is the structuring element, and (a,b) is a position within the structuring element.

Closing:

The closing operation is useful in cases where the objects in an image have small holes or gaps in their boundaries, as it helps to fill these holes and smooth out the object's boundaries. It is often used in image analysis and computer vision applications to improve the quality of the image and make it easier to analyze.

For example, suppose you have an image of a handwritten digit and there are small gaps in the strokes of the digit. In this case, the closing operation can be used to fill in the gaps and make the digit more easily recognizable to a computer vision algorithm.
Overall, the closing operation is an important tool in morphological image processing for cleaning up and improving the quality of images.

The closing of an image f with a structuring element s is defined as:

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

where f(x,y) is the value of the pixel at position (x,y) in the image, s is the structuring element, and (a,b) is a position within the structuring element.

Image to Morphology Output:

Fig.1 Shown Left to Right Morphing based on kernel pixel changing.

Conclusion:

Morphological image processing is a type of image processing that involves the use of mathematical morphology to modify the shape and structure of objects in an image. It involves a set of tools and techniques that can be used to analyze and manipulate the shape and size of objects in an image, as well as to extract features and patterns from the image. Morphological image processing is often used in computer vision and image analysis applications to improve the quality and clarity of an image, as well as to extract useful information from the image. It can be used to remove noise, smooth out object boundaries, fill in gaps, and extract features from an image.

Reference:

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