Morphological Operations for Image Processing : Understanding and its Applications

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Morphological Operations for Image Processing
: Understanding and its Applications

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***Abstract*—Morphological operations are simple to use and works on the basis of set theory. The objective of using morphological operations is to remove the imperfections in the structure of image. Most of the operations used here are combination of two processes, dilation and erosion. The operation uses a small matrix structure called as structuring element. The shape and size of the structuring element has significant impact on the final result. In this paper an attempt is made to understand the basic morphological operations by using them on some standard images. Matlab software is used as the tool for experimenting the morphological operations.**

***Index Terms*— Morphological operation, Structuring Element, Dilation, Erosion, Opening, Closing, Boundary extraction.**

I. INTRODUCTION

When images are processed for enhancement and while performing some operations like thresholding, more is the chance for distortion of the image due to noise. As a result, imperfections exist in the structure of the image. The primary goal of morphological operation is to remove this imperfection that mainly affects the shape and texture of images. It is obvious that morphological operations can be very useful in image segmentation as the process directly deals with 'shape extraction' in an image.

Morphology in context of image processing means description of shape and structure of the object in an image. Morphological operations work on the basis of set theory and rely more on relative ordering of the pixel instead on their numerical value. This characteristic makes them more useful for image processing. The input data for the mathematical morphological operations are two images: raw image and primitive image. Morphological operations are well defined for binary images but are equally valid and are found useful for gray scale images also.

Structuring element is a binary matrix of very small size. The structuring element is applied to interact with the image to get the resultant. The important characteristics to be considered for a structuring element are its shape, size and origin. Shape of the structuring element is the arrangement of ones and zeros in a pattern within the matrix. Size of the structuring element, acts as a 'window' over which the interaction takes place. It also helps to differentiate image objects or features. The origin of the structuring element identifies the pixel of interest that is to be processed. The mechanism of structuring element resembles that of masks used in spatial filtering, it is moved all around the image to be probed to find hit or miss at that location.

The paper is organized as follows, section II describes structuring elements in morphological operations, section III highlights some basic morphological operations, section IV emphasizes on hit-or-miss transformation, section V gives applications of morphological operations and section VI discusses the result obtained on standard test images.

II. STRUCTURING ELEMENTS

Structuring elements are small sets in matrix form or a sub-image used to interact with the image to be probed. It helps us to define some arbitrary neighborhood structures. The precise details can be obtained by choosing suitable structuring element.

Usually the structuring element is represented as a rectangular matrix of odd dimension. Though the origin can be represented in the centre of matrix, it is not restricted to represent in the centre. It is observed in some structure elements, that the representation of origin is present outside the rectangular matrix. The binary structuring element is comprised of zeros and ones since all the elements have values. The ones define the neighborhood of the structuring element. The representation of structuring elements given below shows these arrangements (0s and 1s) it can be observed that in some representations only ones are shown but not zeros this is mainly because all the elements in the grid may not be active members of structuring element. So it is convenient that only ones are used. This is to avoid confusion and also it does not affect the operation since zeros are not considered. In some complicated structuring element representation, in addition to zeros and ones, 'don't care' conditions are also included. These are mostly used for thinning and pruning operations.

The interaction of the structuring element with probing image is such that the origin of the structuring element is translated to all possible pixel locations in the probe image and then the comparison is done between the image pixels and the structuring element. The result is then obtained based on the intended morphological process applied. Two dimensional structuring elements can be classified as flat structuring element and non-flat structural elements. Structuring elements in morphological image processing are same as convolution masks in linear image filtering.

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

		1		
	1	1	1	
1	1	1	1	1
	1	1	1	
		1		

Fig.1 Representation of structuring elements

III. Morphological Operations

Though the morphological operations are based on set theory many of the morphological operations are basically logical operations and are simple to use. The fundamental morphological operations are erosion and dilation. The other morphological operations that are discussed in this paper are dependent on these two basic operations. The following discussion explains few other morphological operations.

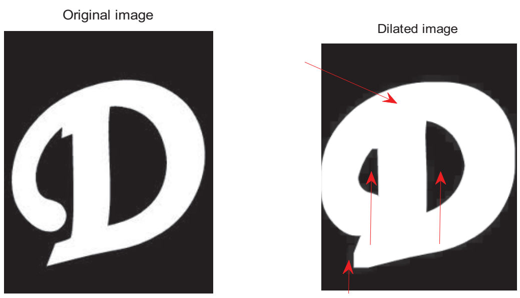
A. Dilation

The dilation operation makes an object to grow by size. The extent to which it grows depends on the nature and shape of the structuring element. The dilation of an image A (set) by structuring element B is defined as

$$A \oplus B = \{z \mid (\widehat{B})_z \cap A \neq \emptyset\}$$

If set B is reflected about its origin and shifted by z, then the dilation of A by B is the set of all displacements z such that $B^{\wedge}$ and A have at least one common element. Dilation, as said above, adds pixels to the boundary elements. The dilation process enlarges the number of pixels with value one (foreground) and shrinks the number of pixels with value zero (background).

Also dilation process is basically used to fill the holes (missing pixels) in a continuous object. The dilation operation, since it adds pixels at the boundary of the object it affects the intensity at that location and as a result blurring effect can be observed. So it can be said that it is analogous to smoothing spatial low pass filters that are used in linear filtering of the image.



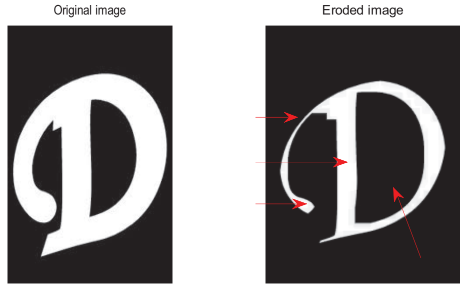
B. Erosion

The erosion operation is complement of the dilation operation in context with the operation effect. That is erosion operation causes object to lose its size. The erosion of an image A bys structuring element B is defined as

$$A \ominus B = \{z \mid (B)_z \subseteq A\}$$

The erosion of image A by structuring element B is the set of all points z such that the structuring element B is translated by z is a subset of the image. This operation results in loss of boundary pixels of the object. The erosion process enlarges the number of pixels with value zero (background) and shrinks the number of pixels with value one (foreground).

The erosion operation removes those structures which are lesser in size than that of the structuring element. So it can be used to remove the noisy 'connection' between two objects. Since the unwanted pixels are 'erased' the net effect is sharpening of the object in an image. The erosion operation is analogous to sharpening high pass filter that are used in linear filtering of an image.



C. Opening

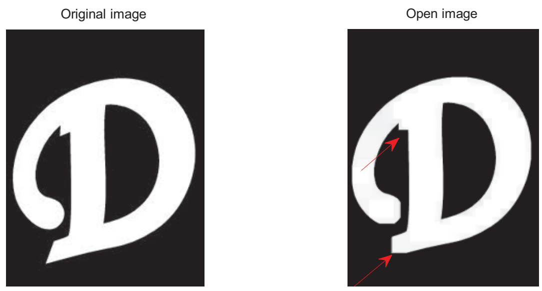
The opening of an image is a combinational operation of erosion and dilation. The opening of an image A by structuring element B is defined as

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

The above definition gives the relationship between opening and erosion & dilation. It states that the opening operation is nothing but the erosion of an image by a structuring element and the resultant is dilated with the same structuring element.

The boundary of the opened image is the points in the structuring element B that reaches the extreme points of the boundary of A as B is 'rolled' around inside of this boundary. The union set operation is also used in literatures to find the points of the opened image.

The opening operation smoothes the outline of an object clears the narrow bridges and also eliminates minor extensions present in the object.



D. Closing

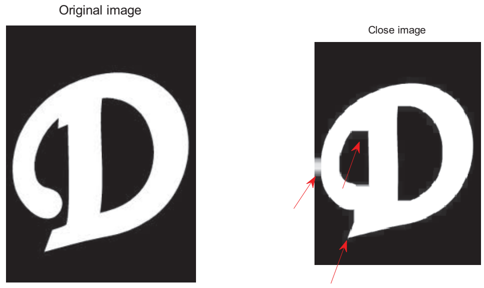
The closing of an image is also a combinational operation of erosion and dilation. It differs from the opening operation in the sense of order of occurrence of erosion and dilation operation. The closing of an image A by structuring element B is defined as

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

The relation between erosion & dilation with closing is given in the above mathematical statement. It shows that closing operation is the dilation of an image A by the structuring element B and the resultant is eroded with the same structuring element.

The boundary of the closed image is the points in the structuring element B that reaches the extreme points of the boundary of A when B is ‘rolled’ over A around outside of its boundary.

The closing operation though smoothes sections of contours it in general blends narrow breaks and thin gaps. As a result it eliminates small holes and fills gaps in the objects boundaries.



IV. HIT-OR-MISS TRANSFORMATION

The hit-or-miss transform basically serves as a tool to identify and detect shapes in the image. The term hit refers to the exact match found in other sets apart from which the reference is taken. This transformation relies on the morphological erosion along with two disjoint structural elements. The first structural element ‘fits’ in the foreground on the considered image and the second structural element has to ‘miss’ it.

If A is the image to be probed and B_1 and B_2 are the structural elements considered then the morphological hit-or-miss transform is defined as the

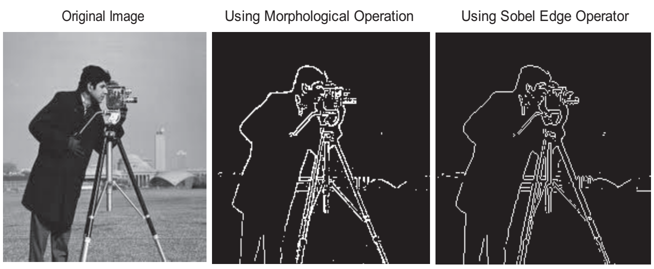
$$A \otimes B = (A \ominus B_1) \cap (A^c \ominus B_2)$$

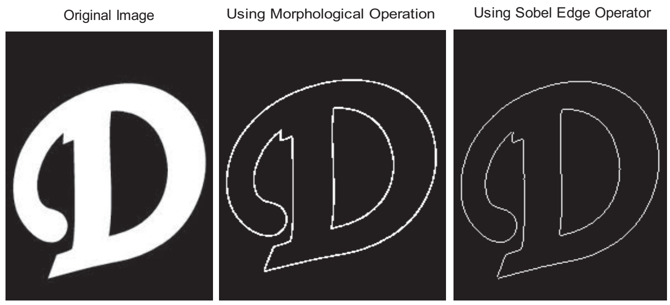
Where B1= D and B_2= W-D and A^c is the complement of the image A. D is the local background enclosed with the window W. This pair of two structuring elements is sometimes called as composite structuring elements.

The above relation says that the resultant transformed image is the set of all points that contains a match in set A by B_1 and a match in A^c by B_2 simultaneously.

V. APPLICATIONS OF MORPHOLOGICAL OPERATIONS

Morphological operations are useful in many applications. To list a few they are used in hole filling, boundary extraction of objects, extraction of connected components, Thinning and thickening and so on. Among these applications the boundary extraction is shown below. For comparison it is done with Sobel edge extraction.





VI. RESULTS AND CONCLUSION

In this paper attempt has been made to understand the basics of the morphological operations used for image processing. We had used image ‘D’ and cameraman images to understand the basic operations and one of the applications. We had used MatLab software to run the codes. We had seen that structuring element plays very important role in morphological operations. It is the size and shape of the structuring element that decides the nature of the output. So emphasis is to be given to its size and shape. Dilation is a morphological operation that adds pixels to the boundary pixels. Erosion of an image with a structuring element causes the boundary pixels to shrink in size. While opening and closing are the operations that are combinations of dilation and erosion. The order of their occurrence changes the nature of the output. Opening operation opens up gap between objects connected by a thin bridge of pixels while closing operation fills the holes in the regions keeping initial region sizes.

We had also tried to prove that the boundary extraction using morphological operation is much similar to the boundary extracted conventionally; we had compared the morphological output with that of the Sobel operator.

We conclude that morphological operations being very simple in approach can be reliable to extract the attributes of the image. This makes them suitable for image segmentation operation.

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