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Morphological Image Processing

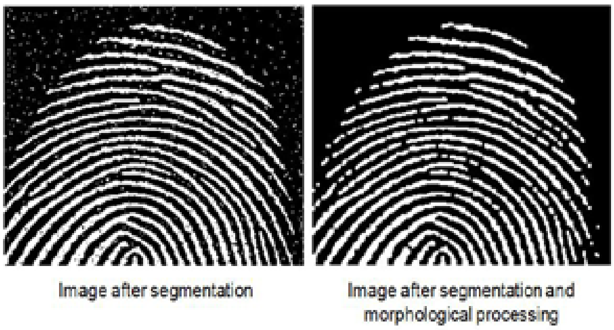
Megha Goyal
Dept. of ECE, Doaba Institute of Engineering and Technology, Kharar, Mohali, Punjab, India

Abstract
The purpose of this paper is to provide readers with an in-depth presentation of the principles and applications of morphological image analysis. This is achieved through a step by step process starting from the basic morphological operators and extending to the most recent advances which have proven their practical usefulness. This self-contained volume will be valuable to all engineers, scientists, and practitioners interested in the analysis and processing of digital images.

Keywords
Introduction,preliminaries,morphological operations, morphological algorithm, some applications, summary.

I. Introduction

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 or we can say that morphology is a branch of biology that deals with the forms and the structure of animals and plants.



Fig, 1:

We use the same word here in the context of mathematical morphology as a tool of extracting image components that are useful in the representation and description of region shape such as boundaries, skeltons etc. goal of morphology operations are simplify image data,preserve essential shape characteristics and eliminate noise.

II. Preliminaries

Basic of Set Operations

The language of mathematical morphology is set theory. Sets in mathematical morphology represent objects in an image.Let A and B be sets. If a is the index of a pixel in A, then we write a $\notin$ A. If a is not in A we write a $\notin$A. If every element that is in A is also in B then A is a subset of B, written, $A \subseteq B$
This is equivalent to the statement

$a \in A \Rightarrow a \in B$

The union of A and B is the collection of all elements that are in one or both set. The union is the set represented by
$C = A \cup B$.
We can write:
$C = \{p \mid p \in A \text{ or } p \in B \text{ (or both)}\}$

A. Union

The operation $C = A \cup B$

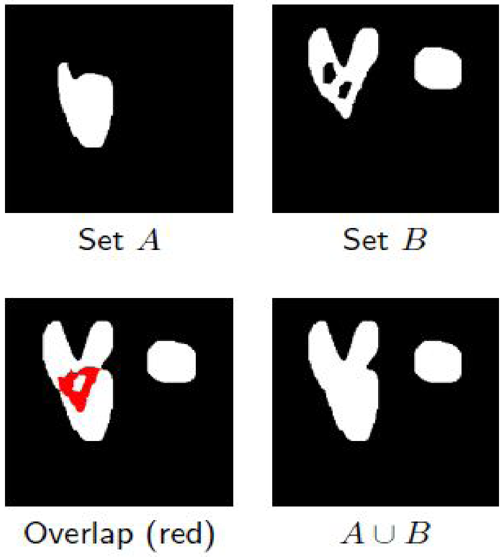


Fig. 2:

Produces a set that contains the elements of both A and B . the fact that some elements are represented in both sets (red pixels)does not affect the result. Note that B itself contains two disjoint subsets.

B. Intersection

The intersection of two points A and B is

$D = A \cap B = \{p \mid p \in A \text{ and } p \in B\}$
It is possible that A and B have no common elements. In that case, we say that they are disjoint.

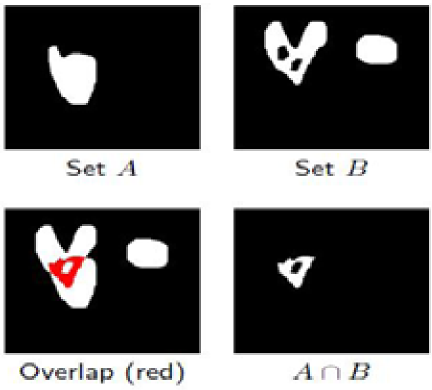


Fig. 3:

C. Complement

The complement A^c is the set of elements that are not contained in A.
A^c = A EQ 0

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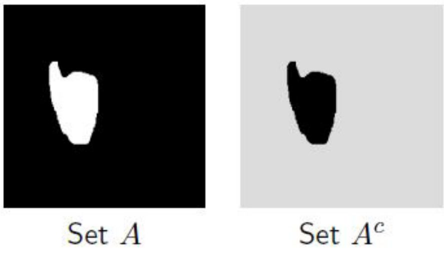


Fig. 4:

D. Reflection

A standard morphological operation is the reflection of all of the points in a set about the origin of the set. The origin of a set is not necessarily the origin of the base. Shown at the right is an image and its reflection about a point (shown in red), with the original image in green and the reflected image in white.

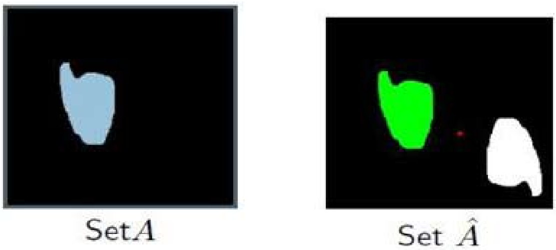


Fig. 5:

III. Morphological Operations

Dilation and erosion are basic morphological processing operations. They are defined in terms of more elementary set operations, but are employed as the basic elements of many algorithms. Both dilation and erosion are produced by the interaction of a set called a structuring element with a set of pixels of interest in the image. The structuring element has both a shape and an origin.

A. Dilation

Let A be a set of pixels and let B be a structuring element. Let $(\hat{B})s$ be the reflection of B about its origin and followed by a shift by s. Dilation, written $A \oplus B$, is the set of all shifts that satisfy the following:$A \oplus B = \{s \mid (\hat{B})s \cap A\}$

Example of Dilation

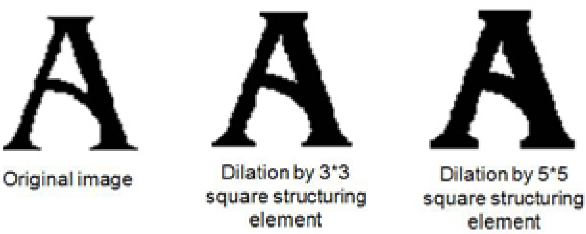


Fig. 6:

Above equation is based on the reflecting B about its origin and shifting this reflection by s. The dilation of A and B then is a set of all displacement. As before, we assume that B is a structuring element and A is the set to be dilated or we can say that the B is flipping about its origin and slides over set (image) A. Dilation is used for repairing breaks and intrusions

B. Erosion

Let A be a set of pixels and let B be a structuring element. Its equation is :

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

Example of Erosion

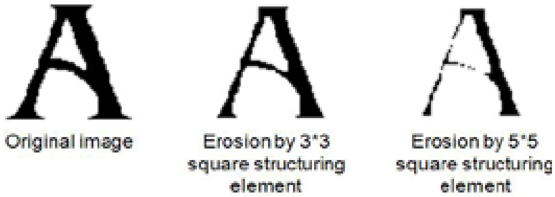


Fig. 7:

Erosion can split apart joined objects and can strip away extrusions. Erosion is used for shrinking or thining operation where as dilation grows and thickens the objects in a binary image.

C. Combination of Erosion and Dilation

Suppose we want to eliminate all the squares except largest one. We can do this by eroding the image with a structuring element of a size somewhat smaller than the objects we wish to keep. After that, we can restore it by dilating them with the same structuring element we used for erosion.

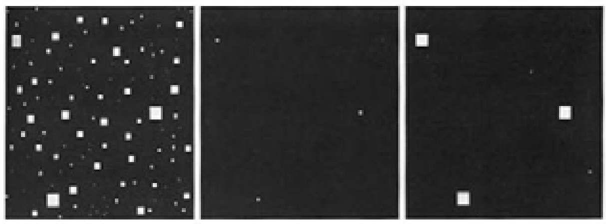


Fig. 8:

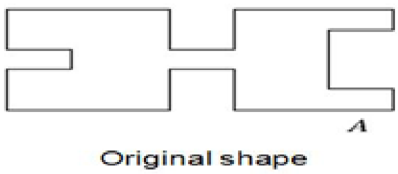
D. Opening and Closing

Opening generally smoothes the contour object, breaks narrow isthmuses, eliminates thin protrusions. Closing also tends to smooth sections of contours but, as opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour.

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

Closing: $A \bullet B = (A \oplus B) \ominus B$

Example of Opening:



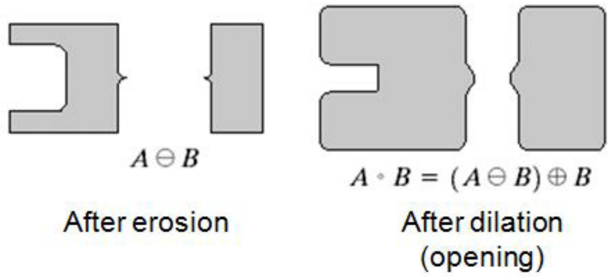


Fig. 9:

Example of Closing

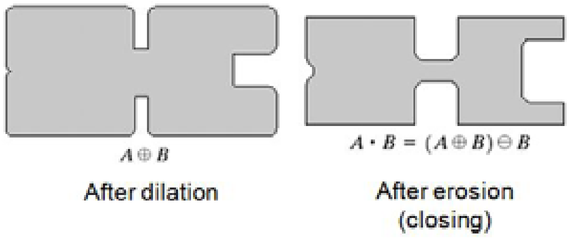


Fig. 10:

E. The Hit – or - Mass Transformation

The Hit-or-Miss transform is a basic tool for shape detection. The objective is to find the location of oneof the shapes in image.

$$A \circledast B = (A \ominus X) \cap [A^c \ominus (W - X)].$$

The small window, W, is assumed that have at least one-pixel-thick than an object. Anyway, in some applications, we may be interested in detecting certain patterns, in which case a background is not required.

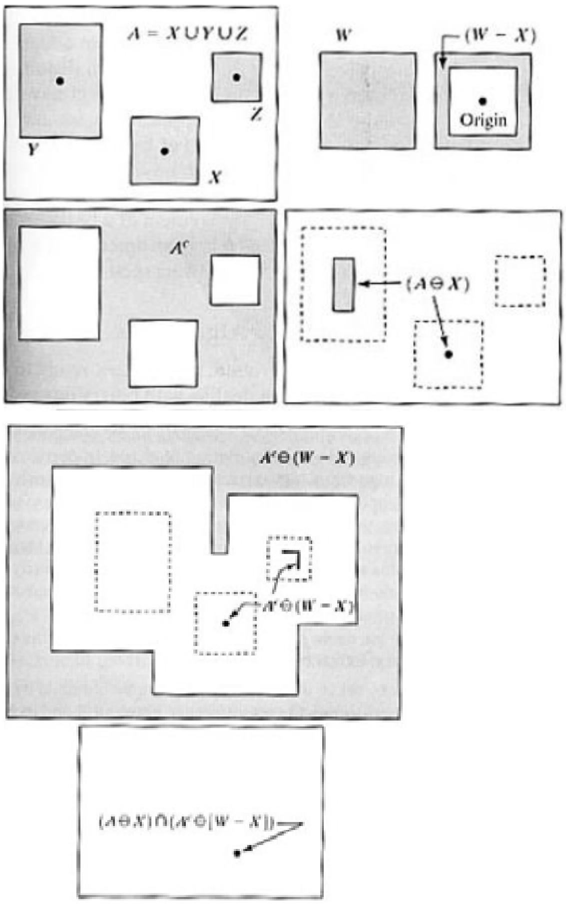


Fig. 11:

IV. Morphological Algorithm

We are now ready to consider some practical uses of morphology. When dealing with binary images, one of the principal application of morphology is in extracting image components that are useful in the representation and description of shape. In particular, we consider morphological algorithms for extracting boundaries, connected components, the convex hull, and the skeleton of region. We also develop several methods (for region filling, thinning, thickening, and pruning) that are used frequently in conjuction with these algorithms as pre- or post-processing steps.

A. Boundary Extraction

The boundary of a set A, denoted by β(A),can be obtained by first eroding A and B and then performing the set difference between A and its erosion.

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

And B is a structuring element.

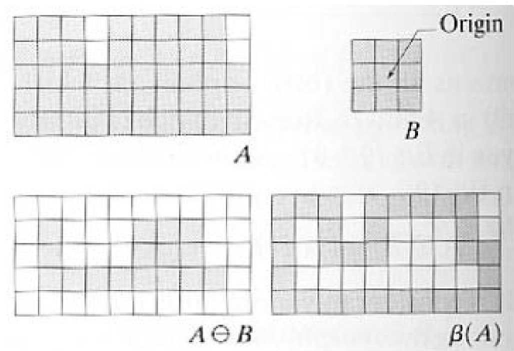


Fig. 12:

B. Region Filling

In this section, we develop an algorithm based on set dilation , complementation, and intersection for filling holes in an image. Let A denote a set whose elements are 8-connected boundaries, each boundary are enclosing a background region (i.e.hole). Given a point in each hole, the objective is to fill all the holes with 1's.

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

The region filling is also called hole filling.
Example:

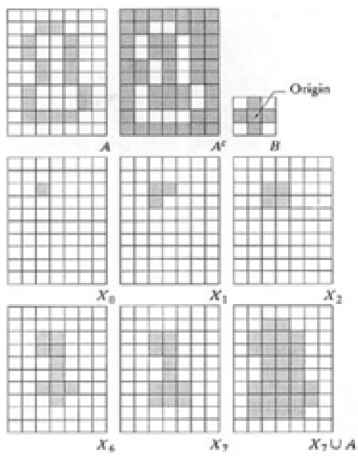


Fig. 13:

C. Extraction of Connected Components

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

The equation is similar to region filling. The only difference is the use of A instead of its complement. After extracting the bones from the background by using a single threshold, to make to make sure that only objects of significant size remain by eroding the thresholded image.

D. Convex Hull

A is said to be convex if the straight line segment joining any two points in A lies entirely with in A.

$$X_k^i = (X_{k-1} \circledast B^i) \cup A \quad i = 1,2,3,4 \text{ and } k = 1,2,3,\ldots$$

with $X_0^i = A$ and

let $D^i = X_{\text{conv}}^i$ ("conv"→convergence)

Then the convex hull of A is

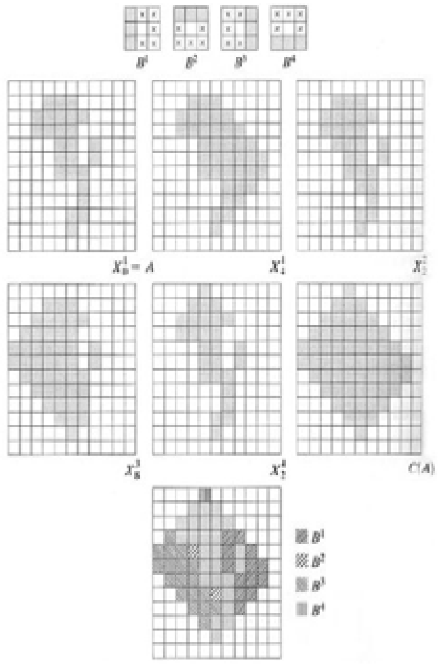


Fig. 14:

E. Thinning

$$\begin{aligned} A \otimes B &= A - (A \circledast B) \\ &= A \cap (A \circledast B)^c \end{aligned}$$

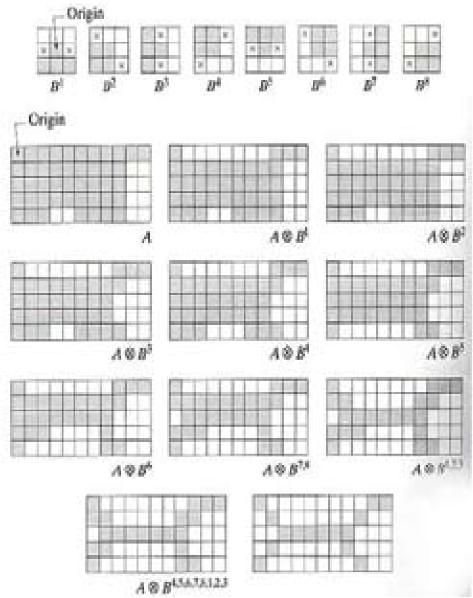


Fig. 15:

F. Thickening

The structuring elements have the same form as in thinning but with all 1's and 0's interchanged. However, a separate algorithm for thickening is seldom used in practice. The usual procedure is to thin the background instead.

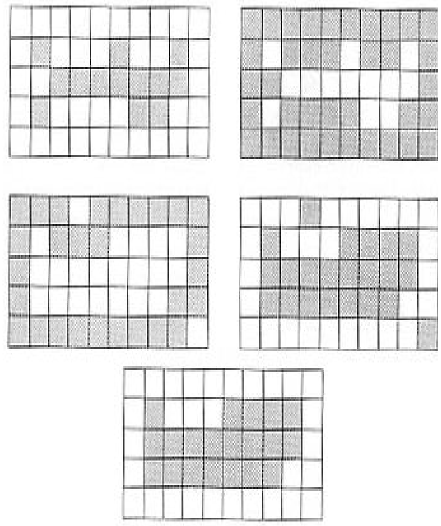


Fig. 16:

G. Pruning

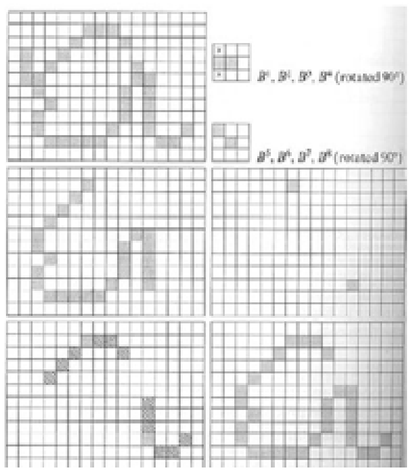


Fig. 17:

$X_1 = A \otimes \{B\}$ Thinning 3 times.

$X_2 = \bigcup_{k=1}^{8} (X_1 \circledast B^k)$ End-point detectors.

$X_3 = (X_2 \oplus H) \cap A$ Grow line.

$X_4 = X_1 \cup X_3$ Restore the character.

V. Conclusion

The morphological concepts constitute a powerful set of tools for extracting features of interest in an image. A significant advantage in terms of implementation is the fact that dilation and erosion are primitive operations.

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Megha Goyal received her Diploma in Electronics and Communication from B.P.S. Mahila Polytechnic, Khanpurkalan (Sonipat), India, in 2006, B.Tech degree in Electronics and Communication from Haryana College of Technology and Management, Kaithal, India, in 2009, the M.tech degree in Electronics and Communication from Doaba Institute of Engineering and Technology, Kharar, India, in 2012. Her research interests include digital signal processing, Embedded System and VLSI. At present, she is a Lecturer in ECE Department of Continental Institute of Engineering and Technology, Punjab Technical University, Jalandhar.

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