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Efficient Morphological Analysis Using Arbitrary Structuring Elements for Security Purposes

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Abstract-The term Mathematical Morphology (MM) mostly deals with the mathematical theory of describing shapes using sets. In morphology, images are represented as sets. This task is investigated by the interaction between an image and a certain chosen arbitrary structuring element using the basic operations of erosion and dilation. The various applications of morphologyinclude skeletonization, prunning, optical character recognition,image analysis,artifacts removal,boundary extraction, etc. It is further extended by the fact that mathematical morphology provides better quality image data for analysis and diagnostic purposes. The process is very efficient due to the use of MATLAB algorithmswhich are helpful for securing meaningful information against different threats like-speckle noise, salt and pepper noise,etc.

Keywords-Mathematical Morphology, image processing, skeletonization, prunning, thinning, morphological filtering, boundary extraction.

I. INTRODUCTION

Morphology is a technique of image processing based on shapes [2].Morphological processing is described almost entirely as operations on sets. A set is a collection of pixels in the context of an image. This means the objects in an image are represented as set of pixels. The field of mathematical morphology contributes a wide range of operators to image processing,all based around a few simple mathematical concepts from set theory.

Suppose, A is a set in Z^2 then following operations from set theory can be used in morphology [1]:

- **i.** a=(a1,a2) an element of A, $a\in A$ if not, then a $\notin A$
- **ii.** $\varnothing$: null (empty) set
- **iii.** A subset of B: $A\subseteq B$
- **iv.** Union of A and B: $C=A\cup B$
- **v.** Intersection of A and B: $D=A\cap B$
- **vi.** Disjoint sets: $A\cap B= \varnothing$
- **vii.** Complement of A: $A^c = \{x|x\notin A\}$
- **viii.** Reflection of B:B = {x|x = -b, for b ∈ B}
- **ix.** Translation of A by $x=(x_1,x_2)$, denoted by $(A)_x$ is defined as:$(A)_x = \{c| c=a+x, \text{ for } a\in A\}$

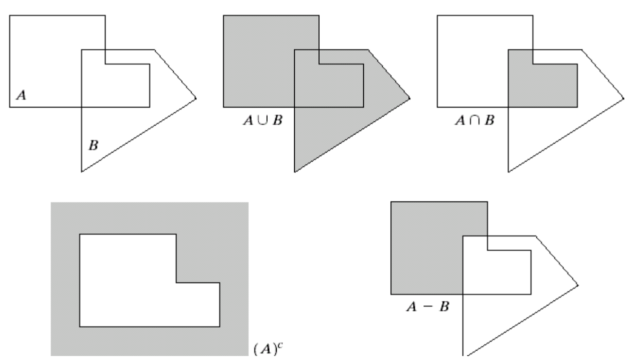

Fig.1 (a) Two sets A and B (b) The union of A and B (c) The intersection of A and B (d)The complement of A (e) The difference between A and B [4].

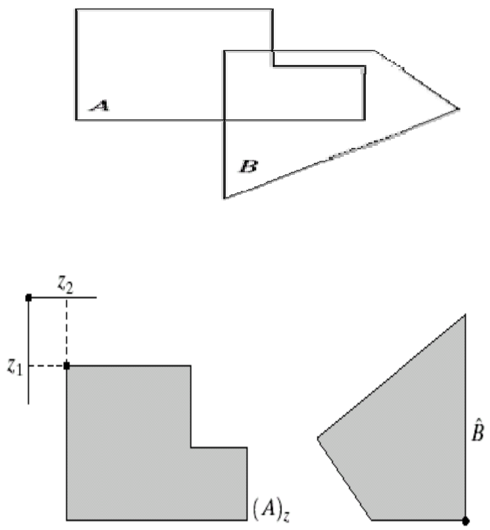

Fig.2 (a) Translation of set A by z. (b) Reflection of set B [5].

Mathematical Morphology uses logical Boolean algebra for this purpose logical AND, OR and NOT are used. All this helps to study the shape, structure, etc. Thus, mathematical morphological operators or filters are nonlinear transformations because they modify geometric features of images.

The operators are particularly useful for the analysis of binary images and common usages include edge detection, noise removal, image enhancement and image segmentation. Morphological techniques typically probe an image with a small shape or template known as a structuring element. The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels.

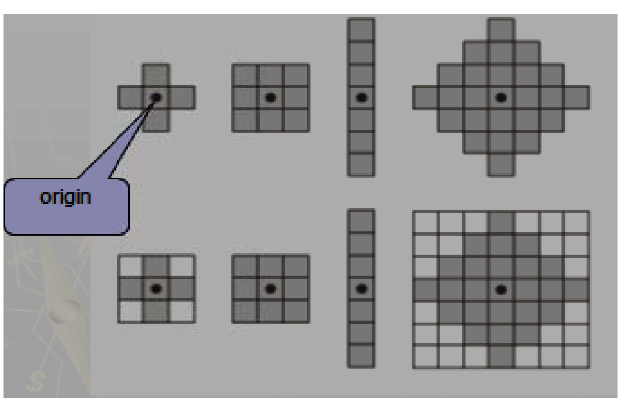

Fig.3 First row shows examples of structuring elements (SEs).Second row shows structuring element converted to rectangular arrays. The dots denote the centers of the SEs [5].

II. MORPHOLOGICAL OPERATORS

There are four basic operators in morphology. These include:

A. *Dilation*

The dilation (D) operation of morphology affects a binary image in the manner that it gradually enlarges the boundaries of regions of foreground pixels (that is, white pixels). Thus areas of foreground pixels grow in size while holes within those regions become smaller. The morphological dilation operator takes two pieces of data as inputs. The first is the image which is to be dilated. The second is a set of coordinate points known as a structuring element. The dilation of A by B, denoted A⊕B, where ⊕ is the operator of dilation [1].Eqn. (3.1) shows dilation operation of image A by structuring element B.

$$A \oplus B = \left\{ x \mid [(\hat{B})_x \cap A] \neq \Phi \right\}$$

Eqn. (3.1)

1) *Algorithm for dilation operation*

- Input the original image.
- Probe structuring element on the original image.
- Perform morphological dilation using ‘line’ structuring element.
- Output the original image.
- Output the morphologically dilated image.

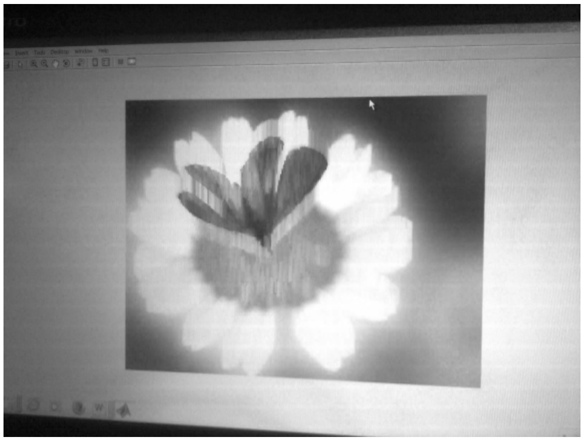

Fig. 4(a) Original Image read into MATLAB.

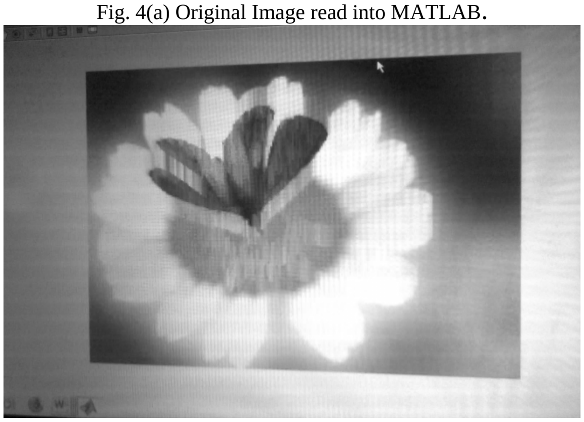

Fig.5 (b)Morphologically dilated image.

B. Erosion

The basic effect of the erosion operator on a binary image is to erode away the boundaries of regions of foreground pixels (that is, white pixels). Thus areas of foreground pixels shrink in size, and holes within those areas become larger. The erosion operator (E) takes two pieces of data as inputs. The first is the image which is to be eroded. The second is a set of coordinate points known as a structuring element. It is this structuring element that determines the precise effect of the erosion on the input image.

The erosion of A by B, denoted by $A \Theta B$, where Θ the operator of erosion [1].Eqn.(3.2) shows erosion of image A by structuring element B.

$$A \Theta B = \{x \mid (B)_x \subseteq A\}$$

Eqn. (3.2)

1) Algorithm for erosion

- Read the image.
- Create a structuring element to probe the original image with it.
- Compute morphological erosion of original image.
- Output the original image and eroded version of it.

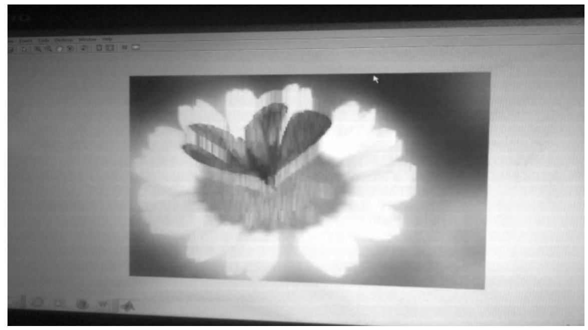

Fig. 6 (a) Original image

Fig.7 (b)Eroded image.

Dilation, in general, causes objects to dilate or grow in size; erosion causes objects to shrink. The amount and the way that they grow or shrink depend upon the choice of the structuring element. Dilating or eroding without specifying the structural element makes no more sense than trying to low pass filter an image without specifying the filter.

C. Opening

The basic effect of an opening is somewhat like erosion in that it tends to remove some of the foreground pixels from the edges of region present in the image. However it is less destructive than erosion in general. With other morphological operators, the appropriate operation is determined by the use of a structuring element or kernel.

The effect of the operator is to preserve foreground regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of foreground pixels. Generally, an opening is defined as erosion followed by a dilation using the same structuring element for both operations. $\circ$ denotes the opening operation [3].Eqn.(3.3) shows opening of image A by structuring element B.

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

Eqn. (3.3)

1) Algorithm for opening

- Read the image.
- Create a structuring element.
- Erode the image with the suitable structuring element.
- Perform morphological dilation on the eroded image.
- Write the original image and its opened version.

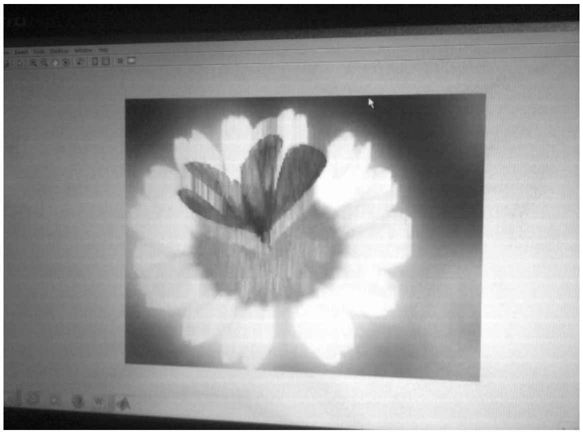

Fig.8 (a) Original image.

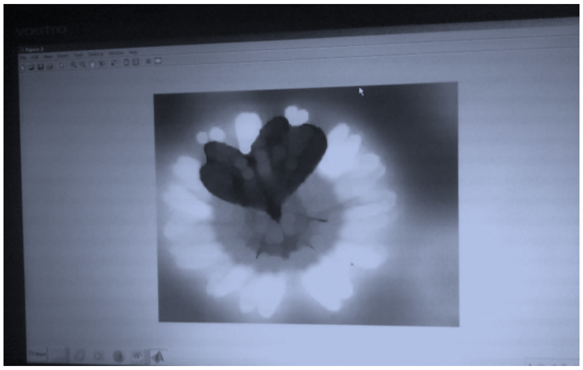

Fig. 9 (b) Opening operation of morphology.

Opening tends to smooth contour, break narrow isthmuses and remove thin protrusion. Opening is the dual of closing that is (i.e.), opening the foreground pixels with a particular structuring element is equivalent to closing the background pixels [6] with the same element. Opening can be very useful for separating out particularly shaped objects from the background, but it is far from being a universal 2-D object recognizer, etc. For instance if we try and use a long thin structuring element to locate, say, pencils in our image, any one such element will only find pencils at a particular orientation. If it is necessary to find pencils at other orientations then differently oriented elements must be used to look for each desired orientation. It is also necessary to be very careful that the structuring element chosen does not eliminate too many desirable objects, or retain too many undesirable ones, and sometimes this can be a delicate or even impossible balance.

D. Closing

Morphological closing tends to smooth sections of contour, fuses narrow breaks and long, thin gulfs and eliminates small holes and filling present in the contour. It is denoted by [1].
Eqn. (3.4) shows closing of image A by structuring element B.

$$A \bullet B = (A \oplus B) \Theta B$$

Eqn. (3.4)

Closing is similar to dilation in that it tends to enlarge the boundaries of foreground regions in an image and shrink background holes in such regions.

But it is less destructive of the original boundary shape. As with other morphological operators, the exact operation is determined by a structuring element. Fig. shows closing operation and its effects.

The effect of the closing is to preserve background regions that have a similar shape to this structuring element, or that can completely contain the structuring element, while eliminating all other regions of background pixels. It is opening performed in reverse and is defined simply as dilation followed by erosion using the same structuring element for both operations. The closing operator therefore requires two inputs: an image to be closed and a structuring element.

1) Algorithm for closing

- Read the image.
- Create a structuring element for probing it with original image.
- Perform morphological dilation.
- Compute eroded version of dilated image.
- Write the original image and the closed form of it.

Fig.10 (a) Original image.

Fig.11 (b) Morphological closing of original image.

III. Applications of Morphology in Digital Image processing

A. Morphological Boundary extraction

There is certain variation in intensity in all types of images. Extraction focuses on detecting the boundaries of required objects based on the discontinuity in pixels of the boundary region and other regions of the image.Mathematical morphology is a tool for extracting image components that are useful in representation and description of region shape, such as boundaries, skeletons and convex hull [7].

B. Filtering for artifacts removal

Morphological filtering is extensively used for edge detection, suppression of noise, artifacts removal from medical images, image compression and its counterparts.

C. Thinning for safeguarding crucial factors

Thinning facilitates a reduced version of an image. Extensive processing of images in various aircraft manufacturing and others uses it.A common use of thinning is in the pre-processing stage to facilitate higher level analysis and recognition for applications such as Optical Character Recognition, diagram understanding, fingerprint analysis, and feature detection for computer vision [8]. Thinning is beneficial especially when speed and complexity of the process or system are crucial factors.

D. Prunning in medical field

Pruning denotes removal of small tail-like structures from the image and also from its already processed version. It is widely used in medical field, etc. and uses Morphological processing.

E. Securing digital image information through Skeletons

Skeletonization is to get a one pixel thin version of an image.Like other morphological operators, the behavior of the skeletonization operation is determined by a structuring element [9]. As an application to Morphology it is used in image analysis, medical field, and various security purposes. There are certain issues in skeletonization like-time consumption is more, etc. which seriously retards its use to limited fields only.

IV. CONCLUSION

Morphological operations help to safeguard the essential data against dangers. Skeletonization, prunning,thinning,morphological filtering,etc. are some of the applications of structuring element based mathematical morphology. Efficiency of morphological processing is enhanced by improved algorithms based on MATLAB.

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