A Study on Implementation of Advanced Morphological Operations

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Abstract
Mathematical morphology stresses the role of shape in image pre-processing, segmentation, and object description. It constitutes a set of tools that have solid mathematical background and lead to fast algorithms. The basic entity is a point set. Morphology operates using transformations that are described using operators in a relatively simple non-linear algebra. Mathematical morphology constitutes a counterpart to traditional signal processing based on linear operators (such as convolution). In images, morphological operations are relations of two sets. One is an image and the second a small probe, called a structuring element, that systematically traverses the image; its relation to the image in each position is stored in the output image. Fundamental operations of mathematical morphology are dilation and erosion. Dilation expands an object to the closest pixels of the neighborhood. Erosion shrinks the object. Erosion and dilation are not invertible operations; their combination constitutes new operations—opening and closing. Thin and elongated objects are often simplified using a skeleton that is an archetypical stick replacement of original objects. The skeleton constitutes a line that is in the middle of the object. To study the pattern trends with shape as primitive the present article experimented the operations of hit or miss, thinning and gradient operations on textures. The experiments clearly shows uniform patterns in cloth textures and where as more number of regions with different topologies are exhibited by the tree bark textures. This factors clearly co-insides with the nature of these textures.

***Key words**:*
Morphology, Hit-or-miss, thinning, gradient.

1. Introduction

Mathematical morphology is a well-founded non-linear theory of image processing [1, 2, 3, 4, 5, 6]. Its geometry-oriented nature provides an efficient framework for analyzing object shape characteristics such as size and connectivity, which are not easily accessed by linear approaches. Morphological operations take into consideration the geometrical shape of the image objects to be analyzed. The initial form of mathematical morphology is applied to binary images and usually referred to as standard mathematical morphology in the literature in order to be discriminated by its later extensions such as the gray-scale and the soft mathematical morphology. Mathematical morphology is theoretically founded on set theory. It contributes a wide range of operators to image processing, based on a few simple mathematical concepts. The operators are particularly useful for the analysis of binary images, boundary detection, noise removal, image enhancement, shape extraction, skeleton transforms and image segmentation [7, 8]. The advantages of morphological approaches over linear approaches are

1) Direct geometric interpretation,
2) Simplicity and
3) Efficiency in hardware implementation.

An image can be represented by a set of pixels. A morphological operation uses two sets of pixels, i.e., two images: the original data image to be analyzed and a structuring element (also called kernel) which is a set of pixels constituting a specific shape such as a line, a disk, or a square. A structuring element is characterized by a well-defined shape (such as line, segment, or ball), size, and origin. Its shape can be regarded as a parameter to a morphological operation.
Mathematical morphology uses tools of algebra and operateswith point sets, their connectivity and shape. Morphological operations are used predominantly for the following purposes:

- Image preprocessing (noise filtering, shape simplification)
- Enhancing object structure (skeletonizing, thinning, thickening, convex hull, object marking)
- Segmenting objects from the background
- Quantitative description of objects (area, perimeter, projections)

Some of the salient points regarding the morphological approach are as follows:

1. Morphological operations provide a method for the systematic alteration of the geometric content of an

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image while maintaining the stability of important geometric characteristics.

2. There exists a well – developed morphological algebra that can be employed for representation and optimization.

3. It is possible to express digital algorithms in terms of a very small class of primitive morphological operations.

4. There exists rigorous representation theorems by means of which, one can obtain the expression of morphological filters in terms of the primitive morphological operations.

2. Methodology

2.1 Hit-Or-Miss Operation

The hit-or-miss operator was defined by Serra but we shall refer to it as the hit-and-miss operator and define it as follows. Given an image A and two structuring elements B_1 and B_2, the set definition and Boolean definition are:

$$Hitmiss(A,B_1,B_2)=\begin{cases} E(A,B_1)\cap \underline{E^c(A^c,B_2)} \\ E(A,B_1)\cdot \overline{E(\overline{A},B_2)} \\ E(A,B_1)-E(\overline{A},B_2) \end{cases}$$

Where B1 and B2 are bounded, disjoint structuring elements. Two sets are disjoint if B1∩B2=φ, the empty set. In an important sense the hit-and-miss operator is the morphological equivalent of template matching, a well-known technique for matching patterns based upon cross-correlation. Here, we have a template B1 for the object and a template B2 for the background.
The results of the application of these basic operations on a test image are illustrated below. In Fig. 1 the various structuring elements used in the processing are defined. The value "-" indicates a "don't care". All three structuring elements are symmetric.

$$B=N_8=\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix} \qquad B_1=\begin{bmatrix}-&-&-\\-&1&-\\-&-&-\end{bmatrix} \qquad B_2=\begin{bmatrix}-&1&-\\1&-&1\\-&1&-\end{bmatrix}$$

(a) (b) (c)

Fig. 1 Structuring elements *B*, B_1, and B_2 that are 3×3 and symmetric.

The opening operation can separate objects that are connected in a binary image. The closing operation can fill in small holes. Both operations generate a certain amount of smoothing on an object contour given a "smooth" structuring element. The opening smoothes from the inside of the object contour and the closing smoothes from the outside of the object contour. The hit-and-miss example has found the 4-connected contour pixels. An alternative method to find the contour is simply to use the relation:

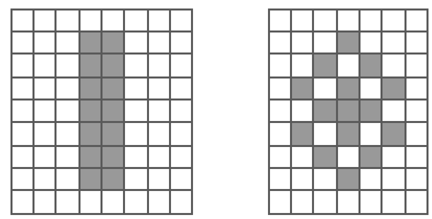
$$4-connected \quad contour - \quad \partial A = A - E(A, N_4)$$

or

$$8-connected \quad contour - \quad \partial A = A - E(A, N_8)$$

2.2 Skeleton

The informal definition of a skeleton is a line representation of an object that is: i) one-pixel thick, ii) through the "middle" of the object, and, iii) preserves the topology of the object.



(a) (b)

Fig. 2 Counter examples to the three requirements.

In the first example, Fig 2(a), it is not possible to generate a line that is one pixel thick and in the center of an object while generating a path that reflects the simplicity of the object. In Fig. 2 (b) it is not possible to remove a pixel from the 8-connected object and simultaneously preserve the topology--the notion of connectedness--of the object. Nevertheless, there are a variety of techniques that attempt to achieve this goal and to produce a skeleton.
A basic formulation is based on the work of Lantuéjoul. The skeleton subset Sk(A) is defined as: Skeleton subsets –

$$S_k(A)=E(A,kB)-[E(A,kB)\circ B] \qquad k=0,1,.....K$$

where K is the largest value of k before the set Sk(A) becomes empty. The structuring element B is chosen (in Z2) to approximate a circular disc, that is, convex, bounded and symmetric. The skeleton is then the union of the skeleton subsets:

$$Skeleton - S(A)=\bigcup_{k=0}^{K} S_k(A)$$

An elegant side effect of this formulation is that the original object can be reconstructed given knowledge of the skeleton subsets Sk(A), the structuring element B, and K:

$$\mathrm{Re}construction - A = \bigcup_{k=0}^{K} (S_k(A) \oplus kB)$$

An alternative point-of-view is to implement a thinning, an erosion that reduces the thickness of an object without permitting it to vanish. A general thinning algorithm is based on the hit-and-miss operation:

$$Thinning - Thin(A, B_1, B_2) = A - HitMiss(A, B_1, B_2)$$

Depending on the choice of B1 and B2, a large variety of thinning algorithms--and through repeated application skeletonizing algorithms--can be implemented.

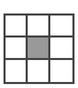
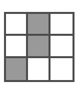
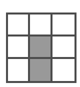
A quite practical implementation can be described in another way. If we restrict ourselves to a 3×3 neighborhood, similar to the structuring element B = N8 in Fig 1(a), then we can view the thinning operation as a window that repeatedly scans over the (binary) image and sets the center pixel to "0" under certain conditions. The center pixel is not changed to "0" if and only if:

i) An isolated pixel is found (e.g. Fig 3 (a)),

ii) Removing a pixel would change the connectivity (e.g. Fig 3 (b)),

iii) Removing a pixel would shorten a line (e.g. Fig 3(c)).

As pixels are (potentially) removed in each iteration, the process is called conditional erosion. Three test cases of equations are illustrated in Fig. 3. In general all possible rotations and variations have to be checked. As there are only 512 possible combinations for a 3×3 window on a binary image, this can be done easily with the use of a lookup table.

(a) (b) (c)

Fig. 3 Test conditions for *conditional erosion* of the center pixel. (a) Isolated pixel. (b) Connectivity pixel. (c) End pixel.

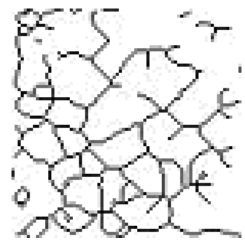
If only condition (i) is used then each object will be reduced to a single pixel. This is useful if we wish to count the number of objects in an image. If only condition (ii) is used then holes in the objects will be found. If conditions (i + ii) are used each object will be reduced to either a single pixel if it does not contain a hole or to closed rings if it does contain holes. If conditions (i + ii + iii) are used then the "complete skeleton" will be generated.

2.3 Morphological gradient

For linear filters the gradient filter yields a vector representation with a magnitude and direction. The version presented here generates a morphological estimate of the gradient magnitude:

$$Gradient(A,B) = \frac{1}{2}(D_G(A,B) - E_G(A,B))$$

$$= \frac{1}{2}(\max(A) - \min(A))$$


(a)

(b)

(c)

Fig. 4 Morphological operators on Acacia (a) Result of Hit or Miss (b) Result of Thinning (c) Results of Gradient morphological gradient.


(a)

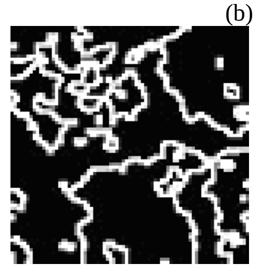
(b)

(c)

Fig. 5 Morphological operators on Gre vililea robust (a) Result of Hit or Miss (b) Result of Thinning (c) Results of Gradient morphological gradient. .

3. Conclusions

Mathematical morphology uses sets to describe image objects and uses simpler shapes called pattern elements to extract information about nature of textures. The present investigation on the study of tree bark and cloth textures as displayed has resulted in-depth usage of morphological methods in structural domain. The advanced morphological skeleton approach resulted a good shape descriptor and evaluated skeleton patterns for tree bark textures, and where as the cloth textures have shown no uniform skeleton patterns and shape descriptor. The results of 1 morphological skeleton approach show greater robustness compared to other approaches.

Finally a conclusion is reached that tree bark textures have a dominant linear and curvilinear patterns and cloth textures have a granular shaped primitives. In the present study the above investigations that are based on the morphology, proved that these methods are useful to discriminate the tree bark and cloth textures and infact, these methods can be adopted in characterization and discrimination of any kind of textures.

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