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Edge detection of Grey Scale Images based on Multi-Structure Elements Morphology

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Abstract- Edge detection is an important pre-processing step in image analysis. Conventionally, Mathematical morphology edge detection methods use single and symmetrical structure elements. But it is difficult to detect complex edge feature with these structure elements, because they are only sensitive to image edges which have the same direction of structure elements. This paper proposed a novel edge detection algorithm based on multi-structure elements morphology of eight different directions. We got five different edge detection results, then opening, closing, top hat transform and bottom hat transform is used to get final results. The experimental results showed that the proposed algorithm is more efficient for edge detection than conventional mathematical morphological edge detection algorithms and differential edge detection operators.

Keywords: Closing, Dilation, Erosion, Edge detection, Mathematical morphology, Multi-structure elements.

I. INTRODUCTION

Edge detection is an important work for object recognition and is also an essential pre-processing step in image segmentation [1-2]. The work of the edge detection decides the result of the final processed image. Mathematical morphology is a new mathematical theory which can be used to process and analyze the images [3-8]. It provides an alternative approach to image processing based on shape concept stemmed from set theory [9], not on traditional mathematical modeling and analysis. In the mathematical morphology theory, images are treated as sets, and morphological transformations which derived from Minkowski addition and subtraction are defined to extract features in images. The choosing of structure element (SE) decides the performance of morphological operation. How to optimize and choose the SE adaptively is a difficult and heated researched field of mathematical morphology. For general morphological edge detection, some simply and symmetrical shape structure elements such as criss-cross, diamond and disk are adopted. But they are only sensitive to image edge which has the same direction of structure elements, and are not so effective to the edge which has the direction other than the structure elements. Therefore, they are difficult to detect complex edge feature. In this paper, a novel edge detection algorithm based on multi-structure elements morphology [9-10] of eight different directions is proposed. These structure elements comprise almost all the directions of lines extend in the image.

II. MATHEMATICAL MORPHOLOGY

The word “morphology” commonly denotes a branch of biology that deals with the form and structure of animals and plants. The same word used here in the context of “mathematical morphology” is a tool for extracting image components that are useful in the representation and description of region shape, such as boundaries, skeletons, and the convex hull [3]. Mathematical morphology is set theory. It is a non-linear filtering, not sensitive in the direction of image edge. Noises can be suppressed in a great measure and the real edges could be detected. So the image is directly detected and noises are filtered out without preprocessing [46].

(a) Basic theory of mathematical morphology

When G. Matheron and J. Serra were engaged in the iron core nuclear analysis of quantitative rock, through in-depth research and the expansion, they built the mathematical morphology which is a rising subject based on strict mathematical theory. The basic ideas and methods are to obtain topological structure information, to gain the more essential shape through some operations of the interaction between object and structuring elements. Images can be observed and processed to achieve the purpose of improving image quality by the basic operations; moreover, each kind of geometric parameter and characteristics can be described and defined such as area, perimeter, connectivity, particles, skeleton, directivity, etc. Morphological image processing has been a major research field of image processing [4]. Mathematical morphology is used to study geometric structure of images. The basic idea above is to apply a structuring element to detect an image, to see whether the structuring element can be filled in the internal of the image well and to validate the validity of the method. The mathematical foundation of morphology and all languages used is set theory which is composed of a group of algebraic calculation. The four basic operations are dilation, erosion, opening and closing. These basic operations are used to process binary image.

(b) Dilation and Erosion

Dilation and erosion are fundamental to morphological processing. In fact, many of the morphological algorithms are based on these two primitive operations.

(1) Dilation

With A and B as sets in Z^2(binary image), the dilation of A by B denoted A⊕ B, is defined as

$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq \emptyset\} \quad (1)$$

The equation (1) is based on obtaining the reflection of B about its origin and shifting the reflection by Z. The dilation of A by B is set of all displacements Z, such that B and A overlap by atleast on element. Based on this interpretation, equation (1) may be rewritten as

$$A \oplus B = \{z \mid [(\hat{B})_z \cap A] \subseteq A\} \quad (2)$$

Set *B* is commonly referred to as the structuring element in dilation, as well as below morphological operations.

(2) Erosion

For sets A and B in Z^2 , the erosion of A by B,denoted AΘB,is defined as

$$A\Theta B = \{z \mid (B)_z \subseteq A\} \quad (3)$$

In conclusion, the equation (3) indicates that the erosion of A by B is the set of all points Z such that B, translated by Z, is contained in A.

Dilation and erosion are duals of each other with respect to set complementation and reflection.

$$(A\Theta B)^c = A^c \oplus \ddot{B} \quad (4)$$

(3) Opening and Closing

As can be seen from the equation (18) and (20), dilation expands an image and erosion shrinks it. Two other important morphological operations are opening and closing. Opening generally smoothes the contour of an object, breaks narrow isthmuses, and eliminates thin protrusion. 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. The opening of set A by structuring element B, denoted A◦B, is defined as

$$A \circ B = (A\Theta B) \oplus B \quad (5)$$

Thus, the opening *A* by *B* is the erosion of *A* by *B* , followed by dilation of the result by *B* .Similarly, the closing of set A by structuring element B denoted as *A•B is*

$$A \bullet B = (A \oplus B)\Theta B \quad (6)$$

In words says that the closing of A by B is simply the dilation of A by B followed by erosion of the result by B.

III. MULTI-STRUCTURE ELEMENTS MORPHO-LOGICAL EDGE DETECTION ALGORITHM

Usually, people use single and symmetrical structure elements morphology to detect image edge. But they are difficult to detect complex edge feature, because they are only sensitive to image edge which has the same direction of structure elements and are not so effective to the edge which has the direction other than the structure elements. In the section, a novel multi-structure elements morphology algorithm is proposed to detect the edge of image.

(a) The Choosing of Structure Elements

The choosing of structure element is a key factor in morphological image processing. The size and shape of SE decide the final result of detected edges. The basic theory of multi-structure elements morphology is to construct different structure elements in the same square window. And these structures elements comprise almost all the line extending directions in the square window.

In the proposed algorithm, following structure elements are used to get the final edge map.

B1=[0,1,0;1,1,0;0,0,0]; B2 =[0,1,0;0,1,1;0,0,0]; B3 =[0,0,0;0,1,1;0,1,0]; B4 =[0,0,0;1,1,0;0,1,0]; B5 = [1, 0, 1; 0, 1, 0; 1, 0, 1];

Diagrammatically:

0	1	0
1	1	0
0	0	0

(A)

0	1	0
0	1	1
0	0	0

(B)

0	0	0
0	1	1
0	1	0

(C)

0	0	0
1	1	0
0	1	0

(D)

1	0	1
0	1	0
1	0	1

(E)

Fig.1: Structure Elements used in PA

(b) Multi-structure elements morphological edge detection algorithm

In the following, we will propose multi-structure elements morphological edge detection algorithm.

Step-1: Input: Load/Acquire the image.

Let 'I' is acquired image.

Step-2: If 'I' is RGB, convert 'I' to gray scale image.

Step-3: Get three edge maps (i.e. E1, E2, and E3) by applying directional structure elements (B1, B2, B3, B4 and B5) on 'I'.

$E1 = \sum_{i=5}^{5}\{((M \bullet B_i) \oplus B_i) - (M \bullet B_i)\}$

$E2 = \sum_{i=5}^{5}\{(M \bullet B_i) - ((M \bullet B_i) \ominus B_i)\}$

$E3 = \sum_{i=5}^{5}\{((M \bullet B_i) \oplus B_i) - ((M \bullet B_i) \ominus B_i)\}$

Where $M = (I \bullet B_i) \circ B_i$

Step-4: $E_f = E1+E2+E3$

Step-5: Get Top-Hat Transform of E_f *with Z*

$E_{tf} = E_f - (E_f \circ Z)$

Where Z is standard 'diamond' structure element of radius '1'.

Step-6: Bottom-Hat Transform of edge map E_f *with Z is*

$E_{bf} = (E_f \bullet Z) - E_f$

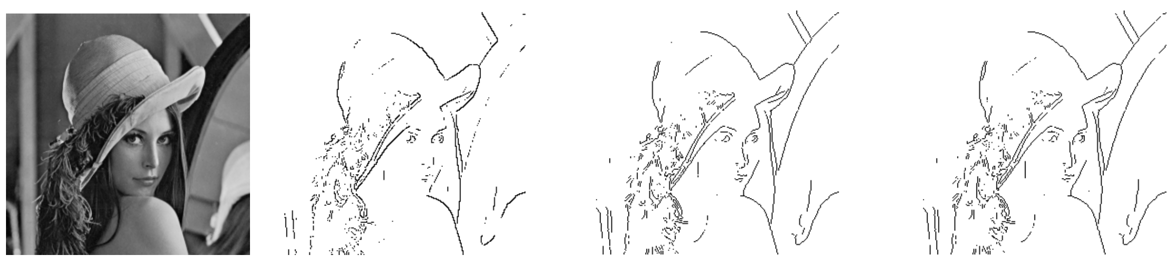
Step-7: $E_{hf} = E_f + E_{tf} - E_{bf}$

Step-8: Apply Thresholding technique to get binary image from E_{hf} *image.*

Step-9: Apply thinning algorithm on binary image (obtained in Step-(8)) to get single pixel wide edges.

IV. EXPERIMENT RESULTS AND ANALYSIS

In this section, the proposed multi-structure elements morphological edge detection algorithm is compared with a variety of existing edge detection methods. Fig.2(a) is the original Lena gray-scale image with 256 gray-scale levels. Fig.2(b), Fig.2(c), Fig.2(d) and Fig.2(e) are the results of processed original Lena image after respectively applying Sobel edge detector, Laplacian of Gaussian (LOG) operator, Prewitt edge detector and Canny edge detector. Fig.2(f) and Fig.2(g) are the results of Canny and proposed algorithm. Proposed algorithm processed original Lena image by respectively applying single and symmetrical morphological edge detect operator with 3×3 SE as shown in Fig.1(a to e). Fig.2(g) is the result of processed original Lena image by the novel multi-structure elements morphological edge detection algorithm proposed in this paper.



(a)Original Lena Image (b)Image obtained using Roberts Edge detection method (c) Image obtained using Sobel Edge detection method (d) Image obtained using Prewitt Edge detection method

(e)Image obtained using LOG operator (f) Image obtained using Canny Algorithm (g) Image obtained using Proposed Edge detection method

Fig.2. Edge detected from Lena Image by various edge detectors (a) Original Lena Image (b) Edge detected by Robert operator (c) Edge detected by Sobel operator (d) Edge detected by Prewitt detector (e) Edge detected by LOG operator(f) Edge detected by Canny method (g) Edge detected by Proposed

According to the experiment results shown in Fig.2(c), Fig.2(d) and Fig.2(e), differential operations such as Prewitt operator, Sobel operator and LOG operator can't detect the edge integrally and continually, and sometimes even anamorphicly like LOG operator. Though Canny operator detects the edge more continually as shown in Fig.2 (f), it can't differentiate the edge from noise. By Fig.2 (g) structure element morphological edge detection operator can detect the edge details better than differential operators, but they can't filter the noise or detect integral edge. As shown in Fig.2(g), the edge detected by the novel multi-structure elements morphological edge detection algorithm proposed in this paper is more pinpointed, integral and continual than the edge detected by other operators mentioned in this paper, and the edge information is more abundant, which can be learnt from the detected edges of buildings and fingers. Moreover, the novel proposed algorithm can filer the noise more successfully than other operators mentioned above

V. **CONCLUSION**

In this paper, a novel multi-structure elements morphological edge detection algorithm is proposed to detect image edge. The experimental results show that the algorithm is more efficient than the usually used single and symmetrical SE morphological edge detection operator and differential edge detection operators such as Canny operator, LOG operator, Sobel operator and Prewitt operator. The detected edge is more pinpointed, integral and continual, and the edge information is more abundant. Moreover, the novel proposed algorithm can filter the noise more successfully than other operators.

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