EDGE DETECTION AND DENOISING MEDICAL IMAGE USING MORPHOLOGY

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ABSTRACT

Medical images edge detection is an important work for object recognition of the human organs and it is an important pre-processing step in medical image segmentation and 3D reconstruction. Conventionally, edge is detected according to some early brought forward algorithms such as gradient-based algorithm and template-based algorithm, but they are not so good for noise medical image edge detection. Although some morphological edge detectors also have been proposed but they are based on fixed structure elements. In this paper, basic mathematical morphological theory and operations are introduced at first, and then a novel mathematical morphological edge detection algorithm based on multi shape structure, is proposed to detect the edge of lungs CT image with salt-and-pepper noise. The experimental results show that the proposed algorithm is more efficient for medical image de-noising and edge detection than the usually used template-based edge detection algorithms and general morphological edge detection algorithms.

KEYWORDS: *Medical image, edge detection, mathematical morphology, de-noising.*

I. INTRODUCTION

Medical images edge detection is an important work for object recognition of the human organs such as lungs and ribs, and it is an essential pre-processing step in medical image segmentation [1-3]. There are many methods for edge detection; they can be divided into two categories: spatial domain detection and transformational domain detection. Classical edge detection algorithms are mostly based on spatial domain detection, such as Sobel operator[4], Laplace operator[5-6], Canny operator[7] and so on . The main functions of these operators are high-pass filters. Despite having respective pertinence and characteristics, they are generally sensitive to noise because of involving the direction. So it is difficult to detect complex edge. Edge detection methods based on transformational domain can suppress noise effectively, but such methods involve a large amount of calculation, they can't meet real-time requirement in many places [7]. Mathematical morphology is a new mathematical theory which can be used to process and analyze the images [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[10]. As the performance of classic edge detectors degrades with noise, morphological edge detector has been studied [11]. In this paper, a novel mathematical morphology edge detection algorithm is proposed based on using multi shape approach whose information at various shapes are integrated to detect lungs CT medical image edge. It is a better method for edge information detecting and noise filtering than differential operation, which is sensitive to noise. And it is a better compromise method between noise smoothing and edge orientation, but the computation is more complex than general morphological edge detection algorithms.

II. DEFINITIONS

The morphologic operations work with *two* images: The original data to be processed and a structuring element. Each structuring element has a shape which can be thought of as a parameter to the operation. Most fundamental morphological operations are morphological *dilation* and morphological *erosion*. Based on these, two compound operations named as *opening* and *closing* are defined. We first give definitions of binary morphologic operations and then that related to gray-scale morphology. In the present work the objects and operations we deal with are in the two-dimensional discrete domain only. Considering the case of binary image, let *A* be the set of points representing the binary one pixels of the original binary image and *B* be the set of points representing binary one pixels of structuring element.

Definition. *Dilation* of a binary image *A* by binary structuring element *B*, is defined as

$A \oplus B = \{a+b \mid \text{for some } b \in B \text{ and } a \in A\}$

Definition. *Erosion* of a binary image *A* by binary structuring element *B*, is defined as

$A \ominus B = \{p \mid b+p \in A \text{ for every } b \in B\}$

Definition. *Opening* of a binary image *A* by a binary structuring element *B*, is defined as

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

Definition. *Closing* of an image *A* by a structuring element *B*, is defined as

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

A gray-scale image with a gray-level function $f(r, c)$ can be thought of a set of points $p=(r, c, f(r, c))$ in the Euclidian three-dimensional space. So gray-scale morphologic operations may be regarded as three dimensional binary morphology. Hence, in gray-scale morphology, both the domain of the function (r, c) and its value $f(r, c)$ are changed.

Definition. The *dilation* of a gray-scale image $f(r, c)$ by a gray-scale structuring element $b(i, j)$ is defined as

$(f \oplus b)(r,c) = \max\{ f(r-i,c-j) + b(i,j) \}$

The domain of $f \oplus b$ is the dilation of the domain of f by the domain of b.

Definition. The *erosion* of gray-scale image $f(r, c)$ by
a gray-scale structuring element $b(i, j)$ is defined as

$(f \ominus b)(r,c) = \min\{ f(r+i,c+j) - b(i,j) \}$

The domain of $f \ominus b$ is the erosion of the domain of f by the domain of b.

Definition. The *opening* of a gray-scale image $f(r, c)$ by a gray-scale structuring element $b(i, j)$ is defined as

$(f \circ b)(r,c) = (f \ominus b)(r,c) \oplus b(i,j)$

Definition. The *closing* of a gray-scale image $f(r, c)$ by a gray-scale structuring element $b(r, c)$ is defined as

$(f \bullet b)(r,c) = (f \oplus b)(r,c) \ominus b(i,j)$

Erosion is a transformation of shrinking, which decreases the grey-scale value of the image, while dilation is a transformation of expanding, which increases the grey-scale value of the image. But both of them are sensitive to the image edge whose grey-scale value changes obviously. Erosion filters the inner image while dilation filters the outer image. Opening is erosion followed by dilation and closing is dilation followed by erosion. Opening generally smoothes the contour of an image, breaks narrow gaps. As opposed to opening, closing tends to fuse narrow breaks, eliminates small holes, and fills gaps in the contours. Therefore, morphological operation is used to detect image edge, and at the same time, denoise the image.

III. NOVEL EDGE DETECTION ALGORITHM

Morphological edge detection algorithm selects appropriate structuring element of the processed image and makes use of the basic theory of morphology including erosion, dilation, opening and closing operation and the synthesization operations of them to get clear image edge. In the process, the synthesized modes of the operations and the feature of structuring element decide the result of the processed image. Broadly saying, the synthesized mode of the operations reflects the relation between the processed image and original image, and the selection of structuring element decides the effect and precision in the result. Therefore, the keys of morphological operations can be generalized to be the design of morphological filter structure and the selection of structuring element. In medical image edge detection, we must select appropriate structuring element by texture features of the image.

3.1. Selection of structure element

Structure element is the basic ingredient of mathematical morphology, the difference of structure element determines directly the difference of geometric information which are analyzed and processed, also determines directly the difference of the amount of data used in computing. Therefore, the selection of structure element is primary and important step for edge detection based on mathematical morphology. The shape and size of structural elements affect the edge detection results: the horizontal structure element is sensitive to the vertical edge; the vertical structure element is sensitive to the horizontal edge; the smaller structure element has weak ability to filter noise, but can detect the edge details; the larger structure element has preferable ability to filter noise, but the edge detected is thicker than expected and small edge details are not preserved.In medical images there are a number of fine details that need to be preserved, simultaneously we need to remove the noise effectively. But the tradeoff between these two requirements makes it difficult to select a single fixed shape structure element which can serve the purpose effectively. After testing on a number of structure elements with different shapes we see that rather than selecting a single structure element of fixed shape, a combination of different shaped structure element gives better result. We have taken the following structure elements to be implemented in the edge detection algorithm;
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];

Digramatically:

0	1	0
1	1	0
0	0	0

B1

0	1	0
0	1	1
0	0	0

B2

0	0	0
0	1	1
0	1	0

B3

0	0	0
1	1	0
0	1	0

B4

1	0	1
0	1	0
1	0	1

B5

3.2 ALGORITHM

By the operation features of morphology, erosion and dilation operations satisfy:

$F \ominus B \subseteq F \subseteq F \oplus B$

Opening and closing operations satisfy:

$F \circ B \subseteq F \subseteq F \bullet B$

What is discussed above shows that dilation and closing operations can expand the processed image while erosion and opening operations can shrink the processed image. But the processed image is similar to the original image[13]. Therefore, in the field of morphological edge detection, the following algorithms are used for image edge detection. The edge of image F , which is denoted by E_d (F) , is defined as the difference set of the dilation domain of F and the domain of F . This is also known as dilation residue edge detector:

$E_d(F) = F \oplus B - F$

Accordingly, the edge of image F , which is denoted by Ee (F) , can also be defined as the difference set of the domain of F and the erosion domain of F .This is also known as erosion residue edge detector:

$Ee(F) = F - F \ominus B$

The dilation and erosion often are used to compute the morphological gradient of image F , denoted by $G(F)$:

$G(F) = F \oplus B - F \ominus B$

The morphological gradient highlights sharp gray-level transition in the input image. The opening top-hat transformation of image F , which is denoted byTHo (F) , is defined as the difference set of the domain of F and the opening domain of F . It is defined as

$THo(F) = F - (F \circ B)$

Similarly, the closing top-hat transformation of image F , which is denoted by THc (F) , can also be defined as the difference set of the closing domain of F and the domain of F . It is defined as

$THc(F) = (F \bullet B) - F$

The top-hat transformation, which owes its original name to the use of a cylindrical or parallelepiped structuring element function with a flat top, is useful for enhancing detail in the presence of shading. The effect of erosion and dilation operations is better for image edge by performing the difference between processed image and original image, but they are worse for noise filtering. As opposed to erosion and dilation, opening and closing operations are better for filtering. But because they utilize the complementarities of erosion and dilation, the result of processed image is only correlative with the convexity and concavity of the image edge. Accordingly, what we get is only the convex and concave features of the image by performing the difference between processed image and original image, but not all the features of image edge.

In this paper, a novel mathematical morphology edge detection algorithm is proposed. Opening-closing operation is firstly used as preprocessing to filter noise followed by closing to smoothen the image. Then the various edge detection techniques have been implemented to extract gradient information of the image. To get the final image aggregation of all the extracted edge information is taken.the algorithm is as follows:

$$E1 = \sum_{i=1}^{5} \{(M \bullet B_i) \oplus B_i - (M \bullet B_i)\} \quad (1)$$

$$E2 = \sum_{i=1}^{5} \{(M \bullet B_i) - (M \bullet B_i) \ominus B_i\} \quad (2)$$

$$E3 = \sum_{i=1}^{5} \{(M \bullet B_i) \oplus B_i - (M \bullet B_i) \ominus B_i\} \quad (3)$$

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

The three formulas can remove noise and enhance the operators' resistance to noise in the condition of retaining the edge details. In order to combine the respective merits of the three formulas, the proposed algorithm detects edge through using formula (1), formula (2), formula (3) sequentially, and then adds and averages the detect results of the three formulas to produce final edge as formula (4) shown.

$$E4 = \left(\sum_{i=1}^{3} E_i \right) / 3 \quad (4)$$

IV. EXPERIMENTAL RESULTS AND ANALYSIS

We have performed all the experiments in Matlab 7[12].We have taken CT Scan image of lungs with salt and pepper noise added to it. For the Sobel's and the Canny's edge detection algorithms, intensity of noise added to the image is $\sigma = 0.01$. For the Morphological edge detector using single and fixed shape structure element(we have used 3x3 square shaped structure element) and the proposed

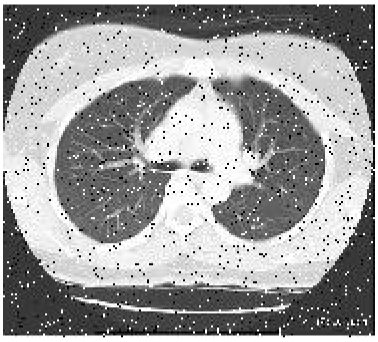

Fig1.

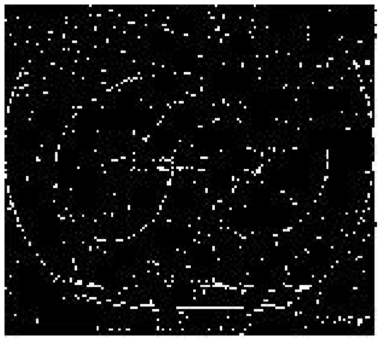

Fig2.

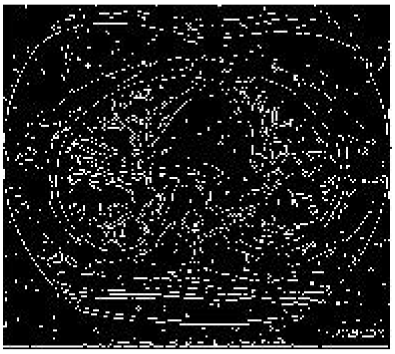

Fig3.

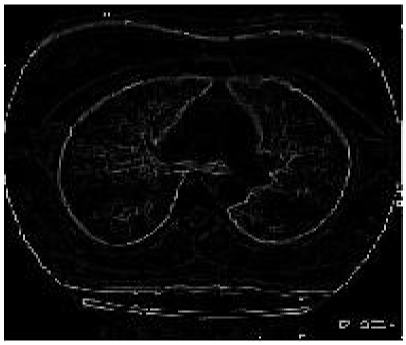

Fig4.

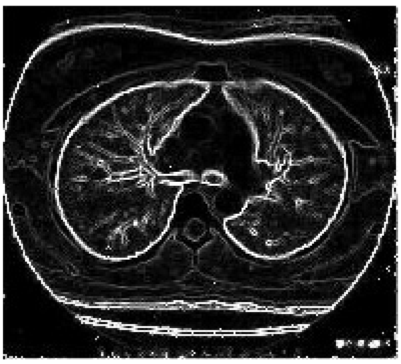

Fig5.

Fig1. CT Scan lungs image with salt & pepper noise of intensity σ = 0.05 added to it.

Fig2. Edge detection result using Sobel algorithm applied on Fig1 with noise intensity in the image reduced to σ = 0.01

Fig3. Edge detection result using Canny algorithm applied on Fig1 with noise intensity in the image reduced to σ = 0.01

Fig4. Edge detection result using previously Morphological edge detection algorithm applied on Fig1.

Fig5. Edge detection result using proposed Morphological edge detection algorithm applied on Fig1.

Morphological edge detection algorithm, intensity of noise added to the image is $\sigma = 0.05$. The reason for using different noise intensities is that it hard to distinguish between the real edge pixel and edge pixels added due to noise when we increase the noise intensity for the Sobel's and the Canny's edge detection algorithms because of the scale of the images is reduced to present them properly in the paper. In short we can say that with increased σ for the Sobel's and the Canny's edge detection algorithms, the resut are even worse than the results presented in the paper using $\sigma = 0.01$. Detection results using the sobel operator, the canny operator, the previous morphological algorithm and the proposed morphological algorithm in the paper are shown in Fig2, Fig3, Fig4 and Fig5 respectively. The detection target in Fig1 is the image with salt & pepper noise. To compare the results statistically we taken three parameters viz mean absolute error(MAE), mean square error(MSE), peak signal to noise ratio(PSNR).

MAE=1/M*N($\sum_{i=1}^{M} \sum_{j=1}^{N} abs\{F(i,j) - U(i,j)\}$)

MSE= 1/M*N ($\sum_{i=1}^{M} \sum_{j=1}^{N} (F(i,j) - U(i,j))$^2)

PSNR= 20log10(255/MSE)

Where U(i,j) is original image of size M x N, F(i,j) is the denoised image of same size

Table 1. Statistical Comparison

Method	MAE	MSE	PSNR
Sobel	152.1551	2.930*10^4	3.4615
Canny	152.0696	2.927*10^4	3.4652
Morphology	49.3498	9.412*10^3	8.3936
Proposed	120.7843	2.084*10^4	4.9458

The statistical results shown in table 1 shows that the proposed method gives better results than Sobel and Canny edge detectors for all the parameters, but previous morphological method is even better for the given parameters. But as we can see visually the proposed method gives much better results in all respects. The detection results visul analysis show that: Sobel operator can't detect edge continuously and can't suppress the effect of noise completely; Canny operator may detect edge excessively despite great continuity and may detect the edge of noise regarding noise as object; Previously used morphological edge detector suppress the noise effectively but gives poor edge detection result as fine edge details are not detected effectively; the proposed algorithm can not only suppress noise, but also detect the edge continuously and completely and meet the requirement of real- time property.

V. CONCLUSIONS

In this paper, a novel mathematic morphological algorithm is proposed to detect lungs CT medical image edge which is based on using a number of different shaped structure elements and using new approach for simultaneously suppressing noise and detecting edge. The experimental results show that the algorithm is more efficient for medical image denoising and edge detecting than the usually used edge detection algorithms such as Sobel, Canny and Morphological edge detector using single structure elements of fixed shape.

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