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Medical Images Edge Detection Based on Mathematical 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. In this paper, basic mathematical morphological theory and operations are introduced at first, and then a novel mathematical morphological edge detection algorithm 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 denoising 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, denoising**

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 [1-2]. The work of the edge detection decides the result of the final processed image. Conventionally, edge is detected according to some early brought forward algorithms like Sobel algorithm, Prewitt algorithm and Laplacian of Gaussian operator [3], but in theory they belong to the high pass filtering, which are not fit for noise medical image edge detection because noise and edge belong to the scope of high frequency. In real world applications, medical images contain object boundaries and object shadows and noise. Therefore, they may be difficult to distinguish the exact edge from noise or trivial geometric features.

Mathematical morphology is a new mathematical theory which can be used to process and analyze the images [4-9]. It provides an alternative approach to image processing based on shape concept stemmed from set theory [10], 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. 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 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. Basic Mathematical Morphological Operations

Mathematical morphology is developed from set theory. It was introduced by Matheron [10] as a technique for analyzing geometric structure of metallic and geologic samples. It was extended to image analysis by Serra [10]. Based on set theory, mathematical morphology is a very important theory, whose operation must be defined by set arithmetic. Therefore, the image which will be processed by mathematical morphology theory must been changed into set.

Mathematical morphology uses structuring element, which is characteristic of certain structure and feature, to measure the shape of image and then carry out image processing. Based on set theory, mathematical morphology is the operation which transforms from one set to another. The aim of this transformation is to search the special set structure of original set. The transformed set includes the information of the special set structure and the transformation is realized by special structuring element. Therefore, the result is correlative to some characteristics of structuring element.

The basic mathematical morphological operators are dilation and erosion and the other morphological operations are the synthesization of the two basic operations. In the following, we introduce some basic mathematical morphological operators of grey-scale images.

Let $F(x,y)$ denote a grey-scale two dimensional image, B denote structuring element. Dilation of a grey-scale image $F(x,y)$ by a grey-scale structuring element $B(s,t)$ is denoted by

$$(F \oplus B)(x,y) = \max\{F(x-s, y-t) + B(s,t)\} . \qquad (1)$$

Erosion of a grey-scale image $F(x,y)$ by a grey-scale structuring element $B(s,t)$ is denoted by

$$(F \Theta B)(x,y) = \min\{F(x+s, y+t) - B(s,t)\} . \qquad (2)$$

Opening and closing of grey-scale image $F(x, y)$ by grey-scale structuring element $B(s, t)$ are denoted respectively by

$$F \circ B = (F \Theta B) \oplus B , \quad (3)$$

$$F \bullet B = (F \oplus B) \Theta B . \quad (4)$$

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. THE PROPOSED MORPHOLOGICAL 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. Detailedly saying, the synthesized mode of the operations reflects the relation between the processed image and origin image, and the selection of structuring element decides the effect and precision and the result. Therefore, the keys of morphological operations can be generalized for 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. And the size, shape and direction of structuring element must been considered roundly. Usually, except for special demand, we select structuring element by 3×3 square.

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

$$F \Theta B \subseteq F \subseteq F \oplus B . \quad (5)$$

Opening and closing operations satisfy:

$$F \circ B \subseteq F \subseteq F \bullet B . \quad (6)$$

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. 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:

$$E_d(F) = (F \oplus B) - F . \quad (7)$$

Accordingly, the edge of image F, which is denoted by $E_e(F)$, 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:

$$E_e(F) = F - (F \Theta B) . \quad (8)$$

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

$$G(F) = (F \oplus B) - (F \Theta B) . \quad (9)$$

The morphological gradient highlights sharp gray-level transition in the input image.

The opening top-hat transformation of image F, which is denoted by $TH_o(F)$, is defined as the difference set of the domain of F and the opening domain of F. It is defined as

$$TH_o(F) = F - (F \circ B) . \quad (10)$$

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

$$TH_c(F) = (F \bullet B) - F . \quad (11)$$

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 complementarity 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. Then smooth the image by first closing and then dilation. The perfect image edge will be got by performing the difference between the processed image by above process and the image before dilation. The following is the novel algorithm:

$$(M \bullet B) \oplus B - M \bullet B . \quad (12)$$

Where

$$M = (F \bullet B) \circ B . \quad (13)$$

IV. EXPERIMENT RESULTS AND ANALYSIS

In this section, the proposed morphological edge detection algorithm is compared with a variety of existing methods for edge detection. Fig.1 is the original lungs CT image with salt-and-pepper noise. Fig.2 and Fig.3 are the results of processed lungs CT images after respectively applying Laplacian of Gaussian operator and Sobel edge detector. Fig.4 and Fig.5 are the lungs CT images processed by mor-


Fig.1. Original lungs CT image with salt-and- pepper noise.

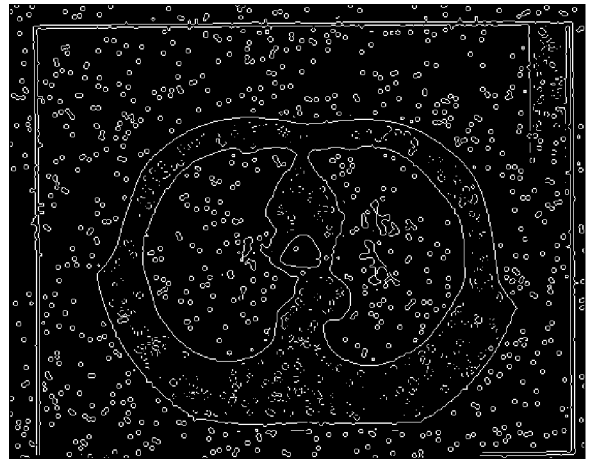
Fig.2. Lungs CT image processed by Laplacian of Gaussian operator.

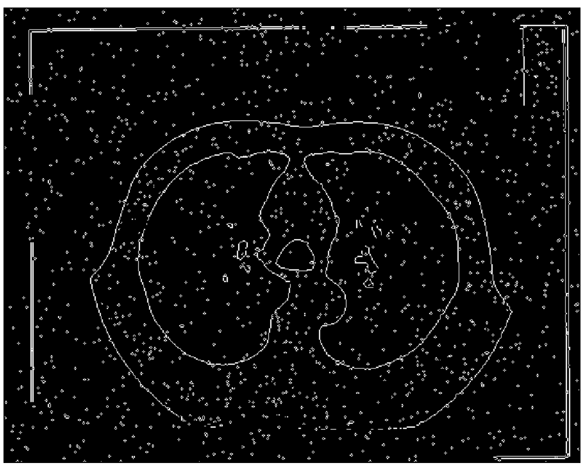
Fig.3. Lungs CT image processed by Sobel detector.

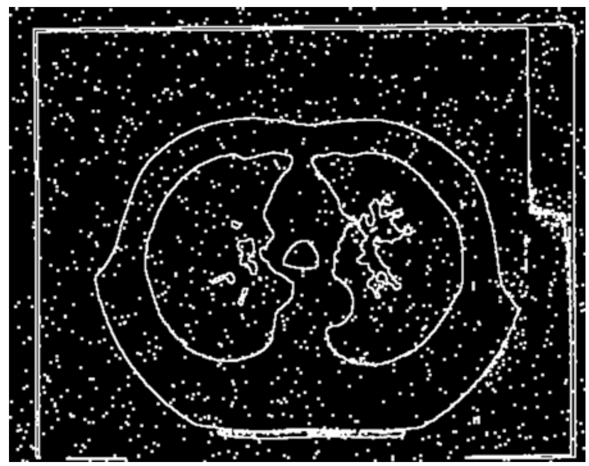
Fig.4. Lungs CT image processed by morphological gradient operation.

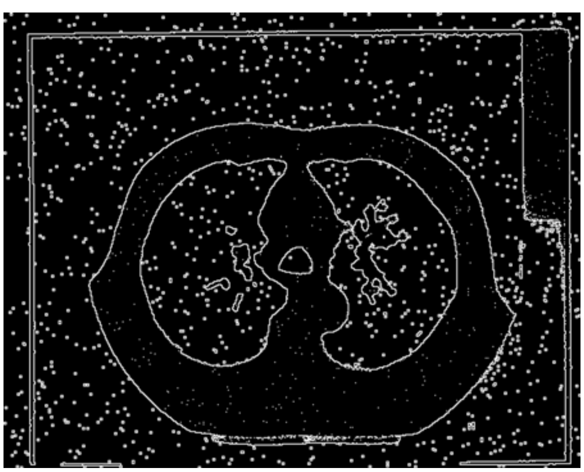
Fig.5. Lungs CT image processed by dilation residue edge detector.


Fig.6. Lungs CT image processed by the novel morphological edge detector.

phological gradient operation and dilation residue edge detector which are denoted by (9) and (7) respectively. Fig.6 is the lungs CT image processed by the novel morphological edge detector proposed in this paper by (12).

According to the experiment results shown in Fig.2 and Fig.3, Laplacian of Gaussian operator and Sobel edge detector detect the lungs edges successfully, but Sobel edge detector fail to detect the outer edge of body, and both of them can't filter the noise. By Fig.4 and Fig.5, the morphological gradient operation and dilation residue edge detector are succeed in lungs and body edges detection, and the detected edges are clearer than the edges detected by Laplacian of Gaussian operator and Sobel edge detector. But both of them fail to filter the noise in despite of the latter is better for noise filtering than the former. By Fig.6, the novel morphological edge detector proposed in this paper is succeed in lungs and body edges detection, but more important than template-based edge detection algorithm and general morphological edge detection algorithm mentioned before, it also filters the noise successfully.

V. CONCLUSION

In this paper, a novel mathematic morphological algorithm is proposed to detect lungs CT medical image edge. The experimental results show that the algorithm is more efficient for medical image denoising and edge detecting than the usually used template-based edge detection algorithms such as Laplacian of Gaussian operator and Sobel edge detector, and general morphological edge detection algorithm such as morphological gradient operation and dilation residue edge detector.

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