Improved Morphological Edge Detection Algorithm for Ultrasound Heart Ventricular Wall Image in the Motion of Its Rotation

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***Abstract*— Ultrasound imaging technology is an effective means of medical diagnosis without wound. The function of viscera is estimated through its locomotor track. To the technology of computer assistant processing and analysis for ultrasound images, the key step is segmenting the edges of tissues accurately. An improved edge detection operator is proposed in this paper for the ultrasound images of cardiac ventricular wall with strong noises and fuzzy edges detected in the motion of their rotation. The algorithm modified the combination of morphological operations, so that the unclear edges of images are avoided. Furthermore, multi-structure elements were also introduced which can reserve integrated edges from different directions of the images. Experiments demonstrate that this edge detector has a better performance on the edge detection of ventricular wall. It can not only keep the edges more accurate than traditional edge detectors, but also satisfy the request of coherent ventricular wall in the analysis of Ultrasound heart images.**

Keywords-edge detection; mathematical morphology; structure element; heart rotation motion

Ⅰ. INTRODUCTION

The motion of cardiac ventricular wall is not only the simple movement of systole and diastole, but also exits the rotation, elastic recoil and the whole shift of the heart in the thorax [1]. The heart rotation motion in the cardiac cycle attaches much important to the estimate of the normal heart function, besides, extremely valuable diagnosis judgment is also provided through the measurement of the rotational angle.

Currently, ultrasound imaging technology is widely used for the detection of cardiac rotation motion without wound. The medical image processing technology has already become the assistant means in medical image analysis. To measure the abnormal heart structure data in cardiac rotation motion, precise geometric characteristics orientation provides important basis for the doctor's diagnosis. But in the analysis for ultrasound images of heart rotation motion, due to the complicated movement model of left ventricular wall in the late systolic and early diastolic stage, Doppler image is not so clear with the vague contour, moreover, the detection of an ultrasound image often contain shadow and noise, so it is hard for us to judge the moving situation of ventricular segmental wall exactly, and the separation of noise from other interference is also a headache. Therefore, in the analysis of the parameters measured in heart rotation motion by image processing, the key step is the edge detection of the tissue structure as ventricular wall, the accuracy of the edge detection determines whether the sequential diagnosis is correct or not.

Edge detection is an important preprocessing step for the medical image processing, object recognition and the follow-up analysis. However, the traditional edge detection method (Sobel operator, Prewitt operator, Laplace operator, etc.)exists widespread paradox between detection accuracy and anti-noise performance[2], recently, edge detection of this problem in mathematical morphology has achieved better results, but the ability of noise smooth and contour accuracy of the edge detection algorithm based on standard morphological transformation has yet to be enhanced.

According to the mathematical morphology, this paper presents a comprehensive modified edge detection algorithm of morphological processing as erosion and dilation, also combined with multi-structure elements to achieve the edge detection of ultrasound heart images, in this way, it can eliminate noises ,reduce the fuzzy edge contours effectively.

The following will give the detail introduction of the improved method.

Ⅱ. IMPROVED EDGE DETECTION ALGORITHM BASED ON MATHEMATIC MORPHOLOGY

Morphological edge detection is the algorithm which carries out operations like dilation, erosion, opening, closing and their combination to get clear image edges by selecting appropriate structure elements [3].

A. Morphological Filtering Algorithm Based on Opening and Closing Operations

To filter noises in the images is an indispensable step for image's pretreatment. To gray level images, filtering the noises refers to morphological smooth in which morphological opening and closing operations are practically adopted.

Opening operation of $B(s,t)$ to $f(x,y)$ can be expressed as:

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$$f \circ B = (f \Theta B) \oplus B \tag{1}$$

Closing operation of $B(s,t)$ to $f(x,y)$ can be expressed as:

$$f \bullet B = (f \oplus B) \Theta B \tag{2}$$

Morphological opening operation can smooth the contour of an image, whittle the narrow part and get rid of thin tine. Using opening operation can not only eliminate some bright details which are relatively small compared with structure element, but also retain holistic gray value of the image and the big bright areas invariable [4]. And morphological closing operation can fill up the gaps of the contour and eliminate some dark details which are relatively small compared with structure element to retain holistic gray value of the image and the big dark areas invariable. Therefore, the combination of the two operations can form a morphological noise filter and filtering all kinds of noises in both bright areas and dark areas.

Based on above analysis, the author adopts the method of both morphological closing and opening operations to accomplish the image pretreatment and filtering noises, using the operation below:

$$f'(x,y) = f(x,y) \bullet B \circ B$$

After this operation, fill $f'(x,y)$ to the modified edge detecting operator undermentioned and then obtain the edge of an image.

B. Improved Edge Detecting Operation Based on Erosion and Dilation

$f(x,y)$ is given as the function of input gray level image, and $B_i(s,t)$ is given as structure elements, then the gray value dilation formula of $B_i(s,t)$ to $f(x,y)$ can be expressed as:

$$(f \oplus B_i)(x,y) = \max\{f(x-s, y-t) + B_i(s,t)\} \tag{3}$$

The gray value erosion formula of $B_i(s,t)$ to $f(x,y)$ can be expressed as:

$$(f \Theta B_i)(x,y) = \min\{f(x+s, y+t) - B_i(s,t)\} \tag{4}$$

Given $G(f)$ refers to the morphological grads of image $f(x,y)$, then it can be expressed through the operation of dilation and erosion.

$$G(f) = (f \oplus B_i) - (f \Theta B_i) \tag{5}$$

Obviously, dilation operation is to find the max value of $f+B$ in the adjacent areas decided by the structure elements and it is the max filtering of a part. The effect to magnify the gray value is prominent to the dots (image edge) whose gray value varies a lot. So, we can get the image edge by finding the differences between original image and the image after dilation operation. And the effect of erosion operation is on the contrary, it also reflects obviously at the edge. We can get the image edge by comparing original image and the image after erosion operation too.

Given $F(x,y)$ refers to the function of image edge, the edge detection operator of dilation difference can be expressed as:

$$F_d(x,y) = f'(x,y) \oplus B_i - f'(x,y) \tag{6}$$

The edge detection operator of erosion difference can be expressed as:

$$F_e(x,y) = f'(x,y) - f'(x,y) \Theta B_i \tag{7}$$

The edge detection operator of morphological grads (dilation and erosion) can be expressed as:

$$G(x,y) = (f'(x,y) \oplus B_i) - (f'(x,y) \Theta B_i) \tag{8}$$

Edge detection operator based on dilation operation always makes the edge of an image blurred and that based on erosion always loses some details of the outputting image edge [5]. To make the edge precise and even coherent, the author referred to researches of some domestic scholars, and made some improvement to edge detection operator. The modified operator constructed as follows:

$$F_{\max}(x,y) = \max\{F_d(x,y), F_e(x,y), G(x,y)\} \tag{9}$$

$$F_{\min}(x,y) = \min\{F_d(x,y), F_e(x,y), G(x,y)\} \tag{10}$$

$$F_{dec}(x,y) = F_{\max}(x,y) - F_{\min}(x,y) \tag{11}$$

The new edge detection operator is defined as:

$$F_i(x,y) = F_d(x,y) + \frac{1}{2} F_{dec}(x,y) \tag{12}$$

Using the improved edge detection operator can add some edge details of an image, which, to some extent, abates the blurriness of the edge.

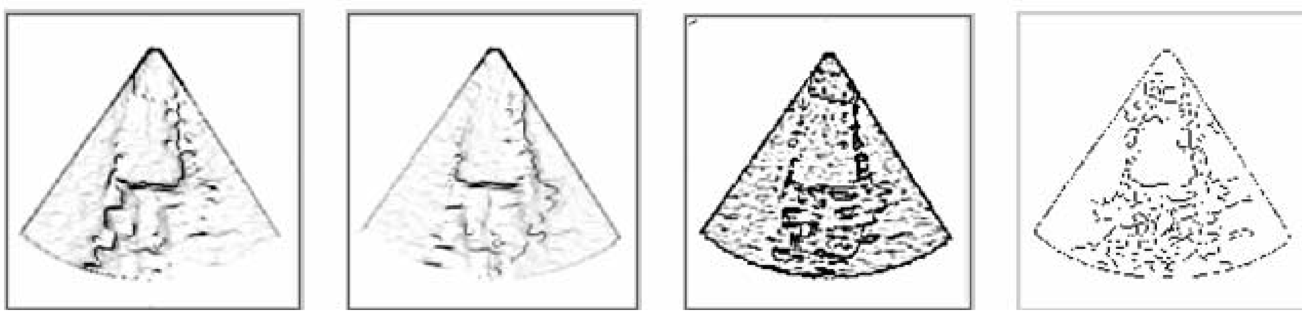
C. Mathematical Morphological Edge Detection Algorithm Based on Multi-structure Elements

Traditional method in morphological edge detection adopts only one structure element to analyze the image and it's hard to perform an ideal effect. Therefore, some complicated targets in the image will be neglected because the edge of rest directions can't be detected, which lead to the loss of integrated image contour [6,7].According to the analysis above, a morphological edge detection algorithm based on multi-structure elements was proposed, and it can detect the edges from different directions. In this paper, structure elements B_i were designed as 3*3 templates of 4 directions as follows:

$$B_1 = \begin{pmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix} \qquad B_2 = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

$$B_3 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix} \qquad B_4 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

(a)Original ultrasound image (b) Result of our algorithm (c) Reverse-colored result of our algorithm



(d)Result of Sobel operator (e) Result of Prewitt operator (f) Result of Laplace operator (g) Result of Canny operator

Figure1. Results of edge detection for the ultrasound image

Use the 4 templates to detect the edge respectively by filling the improved edge detection operator mentioned in chapter Ⅱ.B, and then calculate the average value of the 4 edges in order to obtain final result, as described by Eq.(13):

$$F_o(x,y) = \frac{1}{4}\sum_{i=1}^{4} F_i(x,y) \tag{13}$$

Ⅲ. EXPERIMENTAL RESULTAS

The following will compare the test results of the algorithm proposed in this paper with that of the traditional edge detection algorithm as Sobel, Prewitt, Laplace, Canny operators. The comparison is based on the implementation of edge extraction to the same original ultrasound heart antrum image.

Figure 1 is the results of the simulation using Matlab. Through the experimental results from Fig.1(d)-(g), we can see that the edges sometimes are not entirely coherent, instead, to a certain extent are apart, for Sobel operator and Prewitt operator are not connective while the algorithm in this paper is connective, multi-structure elements can reserve integrated edge from different directions of the image and retain more details. The anti-noise performance of Laplace operator is poor, unable to identify noises and contour details. Although the ability for edge detection of canny operator is better, its edge connection is on the contrary. To enable the experimental results more clearly marked, in this paper, the results experienced reverse-colored processing. Fig.1 (c) shows that using the algorithm the paper proposed to extract the edge, the ventricular wall near apical part will be of a more coherent and clear-cut, the connection of ventricular wall is better. We can have more reservations on the details, more precise orientation, and test results indicate that the algorithm has a better anti-noise performance.

Ⅳ. CONCLUSION

Mathematical morphology method is a bound effective way in medical image edge detection. By using better edge detection operators which have the compounding of various morphological operators, combined with multi-structure elements and multi-scale characteristics, we can solve the issue of coordination between edge detection accuracy and anti-noise performance effectively, and achieve satisfying results.

In this paper the algorithm to extract the ventricular wall edge from the motion of heart rotation can successfully detect the edge of the image, obtain a more detailed contour. It can achieve the orientation accuracy and the details reservations of the ventricular wall contour in the motion of heart rotation, and according to this method, we can carry out the parameter analysis of heart rotation motion by using characteristic reference point operation and accomplish three-dimensional reconstruction of ventricular antrum subsequently.

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