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Contour extraction of echocardiographic images based on pre-processing

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Abstract In this work we present a technique to extract the heart contours from noisy echocardiograph images. Our technique is based on improving the image before applying contours detection to reduce heavy noise and get better image quality. To perform that, we combine many pre-processing techniques (filtering, morphological operations, and contrast adjustment) to avoid unclear edges and enhance low contrast of echocardiograph images, after implementing these techniques we can get legible detection for heart boundaries and valves movement by traditional edge detection methods.

1. Introduction

Echocardiograph imagery is a popular tool for observing the dynamical behavior of the heart. It could provide wealthy and powerful information about the heart function. For that it becomes one of the most commonly ways used to diagnose heart diseases. However, its inherently poor image quality and it have heavy noise.

The major edge detection algorithms fail due to the presence of noise and the low contrast in heart echocardiograph imagery and the improvement of echocardiograph images is very important for the accurate detection of both heart boundary and movement of heart valves. Therefore, noise reduction must be applied before edge detection, in the recent years several techniques proposed to reduce the noise without distorting the relevant clinical details. E Boonchieng et al. [1] proposed a method contained three steps: firstly, image improvement algorithms of noise suppression, histogram, brightness adjustment threshold and median filtering. Second, edge detection with Sobel algorithm and the third used segmentation and computer graphics algorithms to generate contour line of echocardiogram border. Ling et. al. [2] in the mean time modified the combination of morphological operations to avoid the unclear edges of images and presented a comprehensive modified edge detection algorithm of morphological processing as erosion and dilation, also the combination with multi-structure elements to achieve the edge detection of echocardiograph images, where in this way it could eliminate noises and reduce the fuzzy edge contours effectively. Santos et. al [3] analyzed the importance of pre-processing procedure for border extraction in echocardiograph images, explained image filtering, histogram modification and pre-processing effect in the left ventricular boundary extraction. Lacerda et. al. [4] combines classic image processing techniques with Radial search to extract the left ventricular borders from echocardiograph images. High boost filtering and thresholding were used as a pre-processing step, followed by watershed and radial search for segmentation. Then the final contour smoothed by morphological closing. However Ries et al [5]

presented two methods, where both of them apply pre-processing filter to reduce noise and increase contrast by using mathematical morphology, high boost filtering, image segmentation and motion estimation.

Almost all approaches for contours extraction use common image processing procedures, the most important ones being pre-processing and edge detection. The main differences between these approaches are in the level of the pre-processing procedures to achieve an improved image and get an effective boundary tracking.

In this paper, we will present a technique for extracting the contours of the heart in different echocardiograph videos. This technique based on high level of pre-processing to produce clear detection for the heart anatomy in echocardiograph images. This technique consist of two main stages: improvement stage with three operations (median filtering, morphological opening and contrast enhancement), and the second stage apply edge detection and combine two images to get explicit detection.

The paper is organized as followed: section 2 describes our method and the two main stages of the method. Section 3 describes the experimental results of the method. Section 4 contains the conclusion.

2. Method

Our method aims to illustrate the heart boundaries and the valves movement in echocardiograph videos. This illustration present a meaningful contours extraction to medicine practitioners because of the presence of noise and the low contrast of echocardiograph images which may perturb features locations and create unclear view for the heart anatomy.

Our method split the echocardiograph video to a sequence of two dimensional frames and applies two main stages on them: the first stage will be image improvement, where the improvement contains of three operations (filtering, morphological operation and contrast enhancement) to reduce noise and increase contrast. Then, edge detection followed by adding operation will be the second stage to show the edges of the heart anatomy in clear way.

2.1 Image improvement

Noise reduction and contrast enhancement should be implemented in echocardiograph images because of the quality of these types of images. When pre-processing stage performed perfectly the performance of boundary detection will be easier and clearer.

The first operation we used in our method is median filtering [1, 3, 4, 5, 11], it is non-linear filtering could perform high degree of noise reduction without effect the edges. It is simply replace the center value in the window with the median of all the pixel values in the window. An example of median filtering of 3×3 window size is shown below:

6	2	0
3	97	4
19	3	10

→

*	*	*
*	4	*
*	*	*

This example shows 3×3 neighborhood center pixel with value 97, then it processed by sorting pixels [0, 2, 3, 3, 4, 6, 10, 19, 97] and replace the center pixel value by the median of all nine pixels.

In our method, we propose to increase window size to 9×9, where in early stage we tested different window sizes and found that 9×9 give better result. Usually in medical images they prefer to use smaller window size to keep small details which are so important but in our method we care about the contours of the heart and valves and assume that all small details are noise. Thus, the increasing of window size will remove high degree of noise without blurring the edges of the heart.

The second step in improvement stage will be morphological opening where opening is defined as erosion followed by dilation, both operations uses small structure element [10]. It could offer great amount of smoothing and it is an effective operation in medical images. Morphological operations

widely used in medical image improvement [2, 5, 6, 7, 8, 9, 12] because of its ability of smoothing, whittle the narrow part and eliminate bright details.

Last step in improvement stage is adjusting image intensity [1, 3, 4, 5]. This step increases the contrast by adjusting image intensity values.

2.2 Boundary detection

After the image improvement from earlier stage, edge detection algorithm was applied. Edge detection is an essential tool, which is commonly used in many illustration techniques. In our method we will use Sobel edge detection [1, 2] to detect the boundaries between the contours and the background in the image. Sobel detection algorithm use simple convolution kernel to create a series of gradient magnitudes, two convolution kernels, one to detect changes in vertical contrast G_x and another to detect horizontal contrast G_y .

A (source image)

* (Convolution operation)

$$G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \quad (1)$$

And

$$G_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * A \quad (2)$$

The gradient magnitude at each point can be calculated by using:

$$G = \sqrt{G_x^2 + G_y^2} \quad (3)$$

The direction of gradient calculated by:

$$\Theta = \arctan\left(\frac{G_y}{G_x}\right) \quad (4)$$

Finally, we can add one creative step to get legible illustrative view. This step is adding operation, when adding the pixel values of two images (two different images: one from opening step and the other from edge detection step) we could gain better view for the heart contours and the valves movement. This combination helps in clarifying the contours of the heart and give rise to the final illustration view.

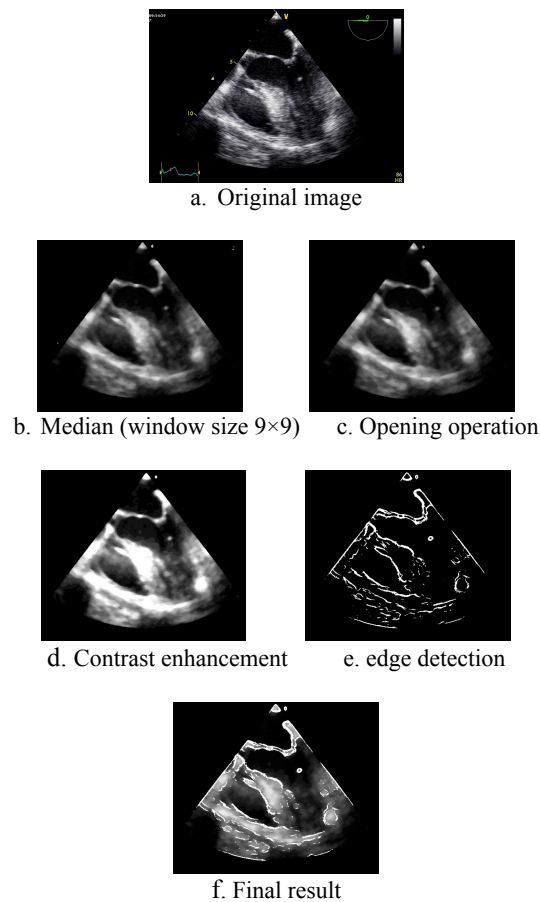


Figure 1. Method steps (a) 2D echocardiograph image. (b) Image filtered with 9x9 median filtering. (c) Apply opening operation. (d) Increase the contrast to improve edge detection. (e) Contour detection. (f) Final result shoes the combination of opening image with detection image.

3. Experimental results

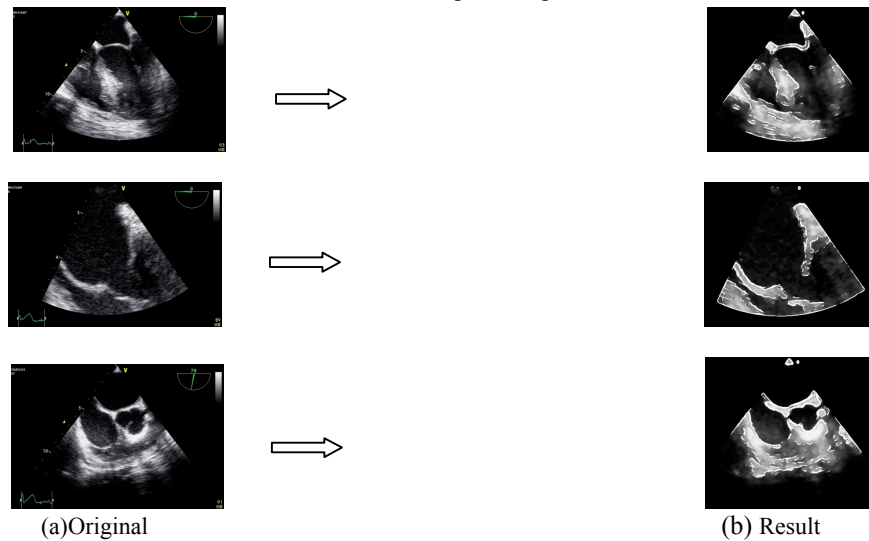


Figure 2. Different example for our method.

This section shows experimental results obtained by our method. About 40 videos of transesophageal echocardiograph used in this study, each video split to a sequence of frames. The length of the sequence has 516 frames and each image has 432×636 pixels.

We have tested our method on different view of two dimensional echocardiograph videos. We apply image improvement on each frame in the sequence (figure 1: (b) median filtering, (c) morphological opening and (d) contrast enhancement). Next, we apply traditional Sobel detection algorithm (figure 1: (e)) and finally enhance the illustration result by combination of two images to present distinct contours extraction for the heart anatomy.

All the experiments performed using Matlab and we test our method on different views of echocardiograph as shown in figure 2. The results evaluated by medical specialist and shows that the proposed method achieved good performance and it succeeds in presenting legible illustration for various echocardiograph videos.

4. Conclusion

In this paper, we present a method to extract the heart boundaries in echocardiograph images where these images are famous with heavy noise and poor quality. Our method based on improving the quality of these images before detection operation, this improvement present great help to get accurate and clear contours extraction.

Image smoothing using non-linear filtering (Median filtering) and morphological operation followed by contrast enhancement results an effective enhancement for detection stage and the combination of two images from different stages produce evident illustration that helps the specialist to diagnose cardiac disease, especially the diagnosis simplified because of the clear definition of heart structure.

The previous examples shown before have demonstrated that the illustration and motion detection for a sequence of frames is greatly influenced by the pre-processing. We can conclude that the proposed method accurately detect the heart motion in images with poor contrast and heavy noise. The application of the pre-processing techniques described here improve the quality of image and enable the original video to be treated in order to get better view that are easier to diagnose.

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