Contour Extraction of Noisy Echocardiographic Images Based on Pre-processing

Ahmed S. J. Abu Hammad

***Abstract*—** Contour extraction from two-dimensional echocardiographic images has been a challenge in digital image processing. This is essentially by reason of the heavy noise, poor quality of these images and some artifacts like papillary muscles, intra-cavity structures as chordate, and valves that can interfere with the endocardial border tracking. In this paper, we will introduce a technique to extract the contours of heart boundaries from a sequence of noisy echocardiographic images, where it started with pre-processing to reduce noise and produce better image quality. In order to do this, we combine many pre-processing techniques (filtering, morphological operations, and contrast adjustment) to avoid unclear edges and enhance low contrast of echocardiograph images, after applying these techniques we can obtain legible detection for heart boundaries and valves' movement by traditional edge detection methods.

***Keywords*—**Echocardiography images, Noise reduction, Edge detection.

I. Introduction

Echocardiography is a valuable tool for imaging the heart and reflects the limits of anatomy and heart movement in two-dimensional cardiac sections. It becomes one of the most common ways used to diagnose heart diseases. Automatic boundary extraction from echocardiography images appears as a clinical important need to produce the most effective and reliable results. However, its inherent 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 the heart echocardiograph image and the improvement of echocardiograph images is very important for the accurate detection of both heart boundary and movement of the heart valves. Therefore, noise reduction must be applied before edge detection.

In this paper, we will present a technique for extracting the contours of the heart in different echocardiography images. This technique based on high levels of pre-processing to produce a clear detection for the heart anatomy in echocardiograph images. This technique consists of two main stages of our method, specifying the method in terms of the flowchart. Main stages contain pre-processing stage, which consists of three operations: median filtering, morphological opening, and contrast enhancement to reduce the noise, the second stage applies edge detection and combines two images to get distinct detection. The results provided by our method are shown in section three with a simple description. Some discussion and conclusion are also presented concerning the usefulness of preprocessing to get better detection.

The paper is organized as follows: section 2 presents related works. Section 3 describes our methodology and the two main stages of the method. Section 4 describes the experimental results of the method. Section 5 contains the conclusion.

II. Related Works

In 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 the Sobel algorithm and the third used segmentation and computer graphics algorithms to generate contour lines of echocardiogram border.

Ahmed Abu Hammad, University College of Science and Technology, Khan Younis, Palestine (e-mail: asj_hammad@hotmail.com).

Lacerda et. al. [2] 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 [3] presented two methods, where both of them apply a pre-processing filter to reduce noise and increase contrast by using mathematical morphology, high boost filtering, image segmentation, and motion estimation.

Santos et. al [5] analyzed the importance of the pre-processing procedure for border extraction in echocardiograph images, explained image filtering, histogram modification and pre-processing effect in the left ventricular boundary extraction.

Ling et. al. [6] in the meantime 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, wherein this way it could eliminate noise and reduce the fuzzy edge contours effectively.

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

III. Methodology

The proposed method consists of two main stages:

1. The image enhancement part which utilizes the median filtering followed by morphological opening and contrast improvement.
2. The detection part which is used to detect the boundaries of the heart boundaries and the movement of the heart valves.

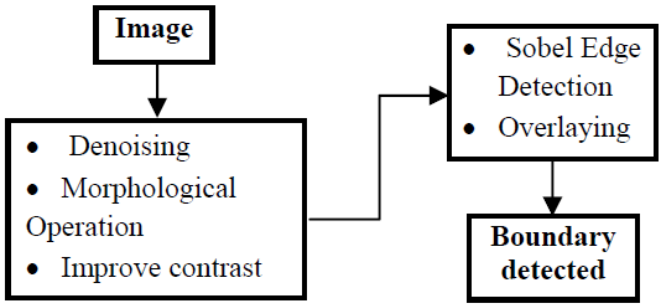


Fig. 1 Block diagram of the proposed algorithm.

3.1 Image Enhancement

The major disadvantage in echocardiograph image is the presence of noise, which perturbs features locations and creates artifacts, thus, we need a method to suppress this heavy noise without presenting additional artifacts or losing image features.

In our method, the first step is applying a median filter, where it is a non-linear technique widely used as a smoother. It is calculated simply by first sorting all the pixel values from the surrounding neighborhood in numerical order and then replacing the pixel being considered with the middle pixel value if the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.

The smallest size of the neighborhood is 3 pixels, in the medical images often they use 5 pixels because they have the problem of noise and poor quality of the image and when

increasing the size of the neighborhood, they gain a better result because anything smaller than the radius of the neighborhood cannot contribute the median value will be eliminated. So, in our method, we propose a simple and effective enhancement, by increasing the size of the neighborhood, which used to define the size of details to 9 pixels. This step is required because we care about the boundaries of the heart and the movement of the valves, and we assume that all small details that are defined as noise can be ignored. After testing different sizes of the neighborhood, we conclude that the size proposed to give a better smoothing performance while sustaining the edge preserving characteristic of the conventional median filter.

After smoothing implementation, a morphological operation seems to be an effective way for more improvement in echocardiographic image. It offers a unified and powerful approach to numerous image processing problems because it could generate a certain amount of smoothing. In our method, we apply opening operation to improve filtering. The opening operation performs an erosion operation followed by dilation operation using predefined structure elements, in the method we use flat and small structure element [4]. The last step of enhancement part will be contrasted adjustment by linearly scaling pixel values between upper and lower limits, the pixels that are above or below the limits will be saturated to the upper or lower limit value.

3.2 Boundary detection

After the image enhancement from an earlier stage, the 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, 6] to detect the boundaries between the contours and the background in the image. The Sobel detection algorithm uses simple convolution kernel to create a series of gradient magnitudes, two convolution kernels, one to detect changes in vertical contrast GX and another to detect horizontal contrast Gy.

A (source image)
$*$ (Convolution operation)

$$Gy = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \quad \text{..... equ. 1,}$$

and

$$Gx = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * A \quad \text{..... equ. 2,}$$

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

$$G = \sqrt{Gx^2 + Gy^2} \quad \text{..... equ. 3,}$$

The direction of gradient calculated by:

$$\emptyset = \arctan\left(\frac{Gy}{Gx}\right) \quad \text{..... equ. 4,}$$

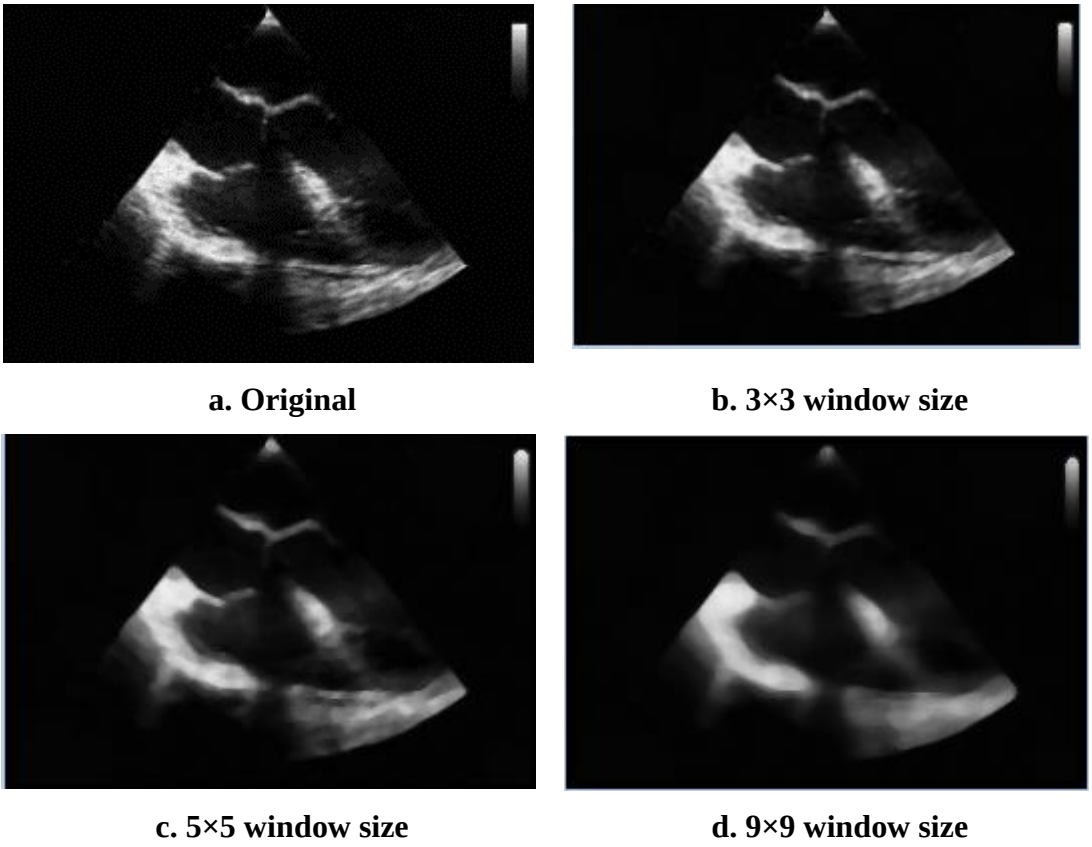
Finally, we can add one creative step to get a legible illustrative view. This step is adding operation when adding the pixel values of two images (two different images: one from opening step and the other from edge detection step) we could gain a better view for the heart contours and the movement of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

IV. EXPERIMENTAL RESULTS

Our method coded in Java. Then it applied to several echocardiograph images to demonstrate the effectiveness of the method. Echocardiograph image gathered from the Internet. The dataset

contains samples for echocardiograph image with JPEG format.

Figure 2 illustrates the effect of changing the size of the neighborhood to get a better reduction of noise. Increasing the neighborhood size gives better smoothing while the edges of the heart still distinct and clear. In figure 2 (d) we see the median filtering applied to higher window size, this neighborhood size gives rise to a more effective noise reduction and less blurring effect.

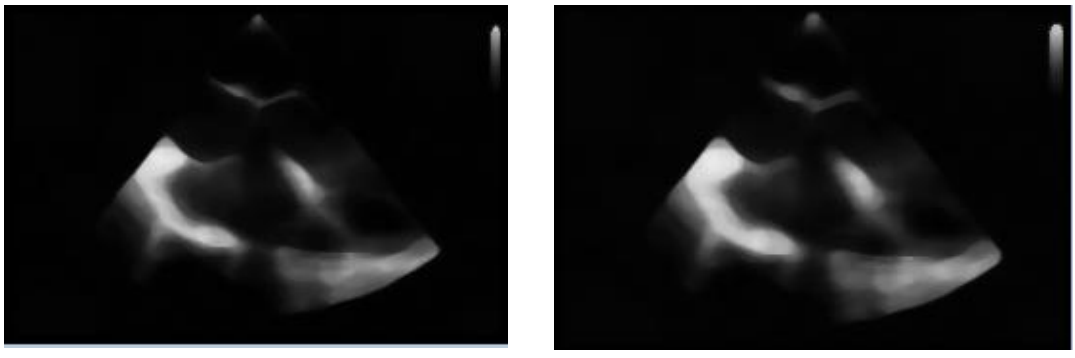


a. Original **b. 3×3 window size**

c. 5×5 window size **d. 9×9 window size**

Fig. 2 Shows Median filtering with different window sizes (window size is the size of surrounding neighborhood. (a) 2D echocardiographic image. (b) Same image after Median filtering with window size (3×3). (c) Median filtering with window size (5×5). (d)Median filtering applied with window size (9×9).

Figure 3 illustrates the effect of opening to get smooth image, whittle the narrow part and eliminate bright details.



a. Erosion **b. Dilation**

Fig. 3 Shows Morphological Opening. (a) Apply erosion operation. (b) Apply dilation operation.

Figure 4 illustrates the effect of contrast adjustment to increase the contrast by adjusting image intensity values.

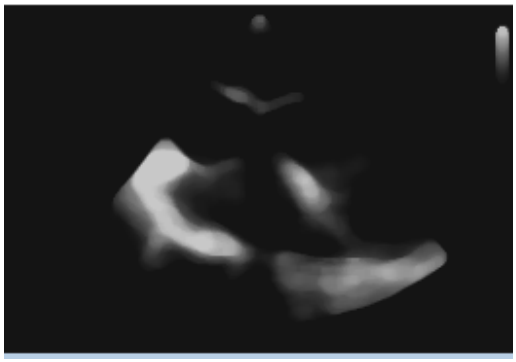


Fig. 4 Apply contrast adjustment with Lower limits = 20 & Upper Limits =200

Figure 5 presents method results after applying traditional Sobel edge detection to get contour extraction.

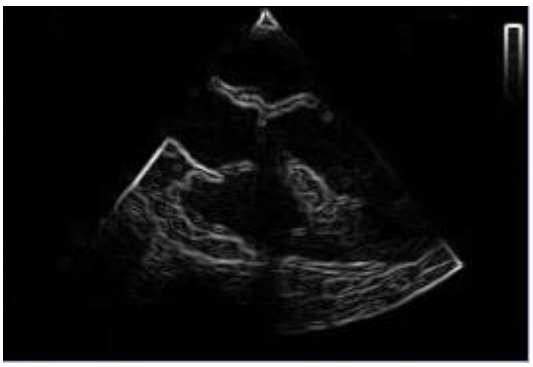


Fig. 5 Apply Sobel edge detection.

Figure 6 presents the final result after combining two images to provide a better illustrative view which could be more understanding.

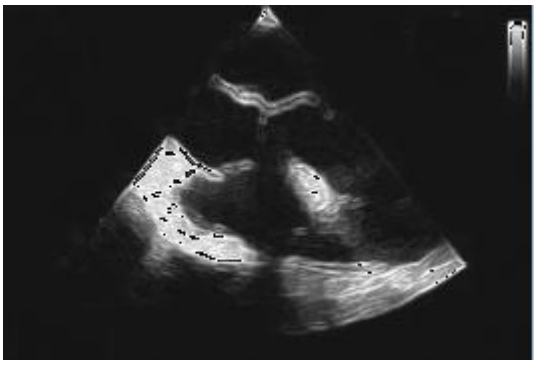


Fig. 6 Shows the final result.

The combination of several methods as a preprocessing stage in our method succeeds in enhancing the low contrast and heavy noise of echocardiographic image and present proper detection for various echocardiograph images.

V. Conclusion

In this work, we demonstrated 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 the detection operation, this improvement present great help to get accurate and clear contour extraction

Image smoothing using nonlinear 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 an evident illustration that helps the specialist to diagnose cardiac disease, especially the diagnosis simplified because of the clear definition of heart structures.

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 detects the heart motion in images with poor contrast and heavy noise. The application of the pre-processing techniques described here to improve the quality of the image and enable the original video to be treated in order to get a better view that is easier to diagnose.

References

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