Pre-processing Importance for Extracting Contours from Noisy Echocardiographic Images

Zinah Rajab Hussein, Rahmita Wirza Rahmat, Lili Nurliyana, M. Iqbal Saripan and Mohd Zamrin Dimon

University Putra Malaysia, National University of Malaysia, Kuala Lumpur, Malaysia.

Summary
Contours extraction from two dimensional echocardiographic images has been a challenge in digital image processing. This is essentially due to 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 present a technique to extract the contours of heart boundaries from a sequence of echocardiographic images, where it started with pre-processing to reduce noise and produce better image quality. By pre-processing the images, the unclear edges are avoided, and we can get an accurate detection of both heart boundary and movement of heart valves.

Key words:
Echocardiography images, noise reduction, edge detection.

1. Introduction

Echocardiography is a valuable tool for imaging the heart and reflects the anatomy border and motion of the heart in two dimensional cardiac sections. It becomes one of the most commonly ways used to diagnose heart diseases. Automatic boundary extraction from echocardiography images appears as a clinical important need to produce most effective and reliable results. Many researchers attempt to identify the echocardiograph boundaries and they got acceptable results in this domain, but it still a challenge because heavy noise and artifacts make feature extraction and tracking difficult. Echocardiograph images have high noise content and suffer from poor contrast. Therefore in case of detect edges in echocardiograph images, the result will present an ambiguous map, missing edge points, containing spurious edge points which are not part of cardiac section. Furthermore, the target borders can have complex and highly variable shapes. Extracting the certain borders from the edge map can therefore be extremely difficult.
The main goal of this work is to develop a computer aided diagnosis in echocardiograph images based on improving the quality and contrast of images before edge detection operation. In the next section, we present the two main stages of our method, specifying the method in terms of flowchart. Main stages contain pre-processing stage which is consist in three operations: median filtering, morphological opening and contrast enhancement to reduce the noise, the second stage apply edge detection and combine two images to get distinct detection. The results provided by our method are shown in section three with simple description. Some discussion and conclusion is also presented concerning to the usefulness of pre-processing to get better detection.

2. Methodology

The proposed method consists of two main stages:

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

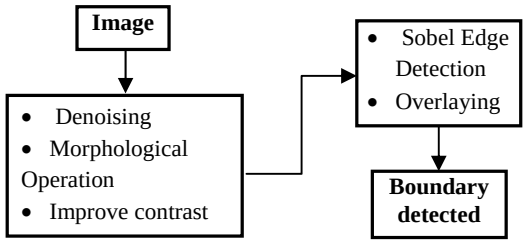

Figure1. Block diagram of the proposed algorithm

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2.1 Image Enhancement

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

In our method, the first step is applying median filter to each frame of echocardiograph video, where median filter is a non-linear technique widely used as smoother. Simply it is calculated by first sorting all the pixel values from the surrounding neighborhood into 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 neighborhood is 3 pixels, in the medical images often they use 5 pixel because they have the problem of noise and poor quality of image and when increase the size of neighborhood they gain better result because anything smaller than the radius of the neighborhood cannot contribute the median value will eliminated. So in our method we propose a simple and effective enhancement, by increasing the size of neighborhood which used to define the size of details to 9 pixels. This step is needed because we care about the boundaries of the heart and the movement of valves, and we assume that all small details that are defined as noise can be ignored. After testing different sizes of neighborhood we conclude that the size proposed give 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 enhance filtering. Opening operation perform an erosion operation followed by dilation operation using a predefined structure elements, in the method we use flat and small structure element. The last step of enhancement part will be contrast adjustment by linearly scaling pixel values between upper and lower limits, pixel that are above or below the limits will saturated to the upper or lower limit value.

2.2 The detection part

Sobel edge detection is applied for obtaining edges from the enhanced image. The Sobel Edge detector uses a simple convolution kernel to create a series of gradient magnitudes, so it uses two convolution kernels, one to detect changes in vertical contrast Gx and another to detect horizontal contrast Gy.

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

and

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

A the source image

* denote the two dimensional convolution operation

.

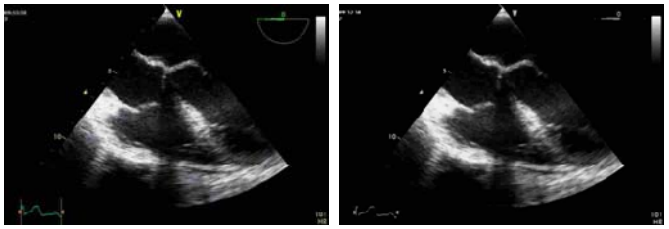
At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude, using:

$$G = \sqrt{G_x^2 + G_y^2}$$

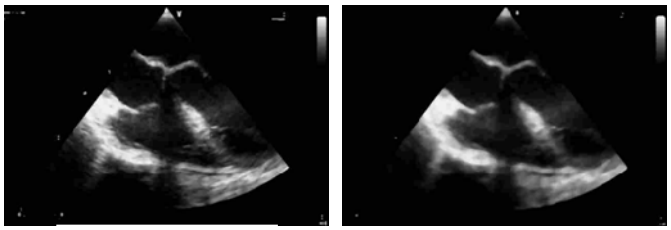
Using this information, we can also calculate the gradient's direction:

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

Once edge has been detected by using Sobel operator, the pixel values of two images will be combined to highlight selected pixels in the input image, where each pixel of the output image is a linear combination of the pixels in each input image. This overlay help in presenting better illustrative view for the anatomy of the heart, where it clarifies the boundaries of the heart and the movement of valves in interactive visualization.



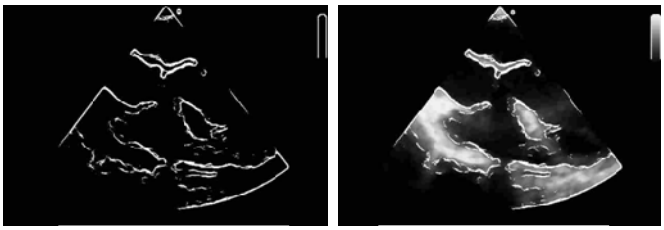
a. Original b. 3×3 window size



c. 5×5 window size d. 9×9 window size

Figure 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 in our method with window size (9×9).

a. Original



b. Contour detected c. Result

Figure 3: The result of our method.
(a) The original 2DE image.
(b) Contour detection after applying our method.
(c) The final result.

3. Results

Our method coded in MATLAB. Then it applied to several echocardiograph videos to demonstrate the effectiveness of the method.

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

Figure 3 present method results after applying traditional Sobel edge detection to get contour extraction and the final result after combining two images to provide better illustrative view which could be more understood.

The combination of several methods as pre-processing stage in our method succeed in enhancing the low contrast and heavy noise of echocardiographic image and present proper detection for various echocardiograph images.

4. Conclusion

In this work, we demonstrated the importance of the pre-processing on the echocardiographic images for contour detection. Image smoothing using non-linear filtering (Median filtering), and morphological operation followed by contrast enhancement results an effective way to get better detection and the last step of combining two images, generates new characteristics when the image become more evident.

We have tested the technique on several echocardiographic images. It is found that the technique can successfully reduce the heavy noise and get legible detection for heart boundaries and valves movement. This technique can be applied on echocardiographic images to provide a better usable and useful illustration for the heart anatomy to medicine practitioners.

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Zinah Rajab received the B.Sc. degrees in computer science from University of Technology, Iraq in 2004.She work in Video Processing and Graphic design for two years and now she is M.Sc. Student in University Putra Malaysia. Her research in the field of computer graphics, especially on Echocardiographics Images

Rahmita Wirza recieved the B,sc. And M.Sc. degrees in Science Mathmatics from University Science Malaysia, in 1989 and 1994, respectively. During 1989 to 1990 she work as research assistance in Department of Physics in University Science Malaysia experimenting on Ozone layer measurement at the Equatorial region, before working as tutor in Universiti Putra Malaysia. She recieved her PhD in Computer Assisted Engineering from University of Leeds, U.K. at this moment she is working in faculty of Computer Science and Information Technology as lecture and acting as head of Multimedia department. Among her focus research area are Computer Graphics and Applications, Computer assited Surgery and Computational Geometry.

Lili Nurliyana completed PhD from University Kebangsaan Malaysia. Currently she is Senior Lecturer at the Department of Multimedia, Faculty of Computer Science and Information Technology, University Putra Malaysia. She has expertise in the area of virtual reality, video retrieval, and multimedia information retrieval. Her research interest includes video retrieval, computer game and animation.

M. Iqbal Saripan, Ph.D. MIEEE AMInstP GradBEM, received his B.Eng. degree in Electrical-Electronics Engineering from the Universiti Teknologi Malaysia (2001). He completed his Ph.D. degree in the area of computer vision/medical imaging from the University of Surrey, United Kingdom (2006). Currently, he is a Lecturer and also the Head of the Embedded and Intelligent Systems Engineering Research Group at the Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia. His research interests are in the area of digital image processing, especially in medical imaging, speech processing, artificial intelligence and embedded system.

Mohd Zamrin Dimon received his MD from the Universiti Kebangsaan Malaysia (1992) and post-graduate degree in Surgery (MMED Surgery) from Universiti Sains Malaysia (2000). He had his subspecialty training in cardiothoracic surgery at National Heart Institute (IJN), Kuala Lumpur, Malaysia (2000- 2003) and at Cardiothoracic Centre, Sarawak Heart Centre, Sarawak (2003 – 2004). he performed more than 1,500 cardiac surgeries including coronary artery bypass grafts (CABG), aortic and mitral valve procedures, thoracic surgeries including lung resection for malignancies, video-assisted thoracoscopic surgery, endoscopic radial artery harvesting and endoscopic saphenous vein harvesting and he is a Consultant Cardiothoracic Surgeon at UKM Medical Centre. Kuala Lumpur, Malaysia (2006).