

Edge-Detection and Segmentation Methods for Two-Dimensional Echocardiograms

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Abstract

The purpose of this Edge Detection and Segmentation Method for Two-Dimensional Echocardiogram is to present the procedures to detect and segment an image from Two-Dimensional Echocardiogram and to generate a scanline that can be used to detect the distance between two endocardiums which is useful to analyze heart disease. This method applies image processing and computer graphic algorithms which were divided into 3 steps. Firstly, we used image improvement algorithms of noise suppression, histogram, brightness adjustment, threshold and median filtering. Then, Edge Detection algorithm with sobel compass gradient mask was applied to show the edge of endocardium border. Finally, segmentation and some computer graphics algorithms were used to identify and generate contour line of the endocardium border. Later in the study, Pearson correlation coefficient was used to evaluate performance of this method compared with that of manual track. The average correlation computes from this method is 0.9 which shows a good result because 0.9 is very close to 1. However, some part of contour line has a big error value. The unexpected result from incomplete of endocardium border came from color value of some part of border very close to background or noise color value. This problem occurred in first step can be solved by carefully collecting in collection process.

1. Introduction

Recently, heart disease became one of the illnesses with high risk and mortality rate. The diagnosis of the illness requires the examination through many methods. One of the popular techniques is Echocardiogram. This method of Echocardiography is used to detect the region wall motion of the heart which is the important means to

diagnose the patient with coronary artery disease. Normally, Echocardiogram device would consist of instruments or programs developed to be used particularly on the machine. At the same time, the manufacturer would develop another program to be used on computers so that the physicians can examine the pictures taken from the Echocardiogram device and, later, diagnose the conditions of the patient.

Mainly, the physicians would use the program to observe the region wall motion, which indicates the overall working efficiency of the heart, and also to diagnose any malfunctions happened with the region wall. However, there are some restrictions in using the program as this type of picture-presented programs is limited and, mostly, comes with the machines from the manufacturers. The result is the shortage of the program which can be used with other computers.

2. Methods

2.1 Image Improvement

2.1.1 Noise Suppression

The color data of each pixel from the next picture frame was used to calculate (m loops) for average value.

$$f_k^{(m)}(i, j) = \frac{1}{2} \{f_{k+1}^{(m-1)}(i, j) + f_k^{(m-1)}(i, j)\}$$

This step develops the effect of Noise reduction and reduces the dispersion of the Noise area so that it would be easy for the Threshold process to filtrate the colors.

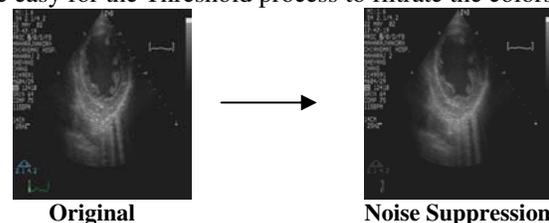


Figure 1. & 2. Sample pictures of Echocardiogram before and after Noise Suppression process

2.1.2 Threshold and Histogram

In this step, histogram of the picture was generated and used to find the pixels with the lowest color value (which is not background color). This group of pixels would be deleted by adjusting of the color value to be equal to background color (0). Some area of Noise with lower color value than that of the edge would be removed before the Threshold process as follows:

$$MinColor = FindMin(Hist, level)$$

when Hist means histogram of the picture and level refers to starting point on finding the lowest value.

$$F(i, j) = \begin{cases} 0 & (F(i, j) < (MinColor + Distance)) \\ F(i, j) & (F(i, j) \geq (MinColor + Distance)) \end{cases}$$

when $Distance = \{1, 2, \dots, (255 - MinColor)\}$

2.1.3 Median Filtering

The color value of each point was filtered by using the color values of the points around to estimate the new value of that specific point. The process was done using 7x7 matrix to calculate the value from 3 rows and 3 columns around the point. The data from the matrix would be arranged and the value in the center was used as

$$F = \begin{bmatrix} a11 & a12 & a13 & a14 & a15 & a16 & a17 \\ a21 & a22 & a23 & a24 & a25 & a26 & a27 \\ a31 & a32 & a33 & a34 & a35 & a36 & a37 \\ a41 & a42 & a43 & C & a45 & a46 & a47 \\ a51 & a52 & a53 & a54 & a55 & a56 & a57 \\ a61 & a62 & a63 & a64 & a65 & a66 & a67 \\ a71 & a72 & a73 & a74 & a75 & a76 & a77 \end{bmatrix}$$

the color value of the point.

C = color value in rows and columns of the picture which later was used for data arrangement

Sort(a11, a12, a13, ..., a77)

NewC = F(25) newC is the new color value at rows and columns



Threshold & Histogram

Median Filtering

Figure 3. & 4. Sample pictures of Echocardiogram after Threshold & Histogram and Median Filtering processes

2.1.4 Brightness Adjustment

Then, HighPass Mean Filter was used to adjust the brightness of the picture while the Histogram Distribution was done through Histogram Equalize process in order to increase the brightness of the edge and further distinguish the difference between the color value of the edge and residue.

After the prior processes, Threshold procedure was

applied again to filter the picture so that only the edge was left and to diminish any residue in the void of Endocardium before Median Filtering with the range of 2 columns and rows around each point was reprocessed.

The level adjustment of the Histogram was implemented in order to adjust the new distribution of the histogram that would show the difference of color value between the edge and residue. The process started by finding the level of histogram of the picture then adjusted it with Cumulative Distribution Function (CDF) as follows:

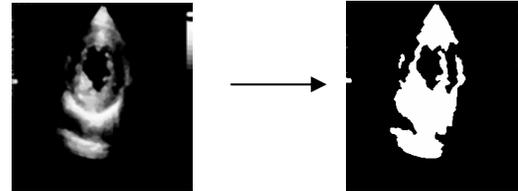
$$S_k = \sum_{j=0}^k n(j)$$

when S_k = new adjusted histogram, and $n(j)$ = value of histogram at the point j

then the color value of histogram was adjusted again to be in the range of 0 – 255 with the equation as follows:

$$S'_k = \frac{S_k - S_0}{S_{255} - S_0} \cdot 255$$

when S'_k = new histogram within the color range between 0 – 255



Brightness adjustment

Histogram Equalization

Figure 5. & 6. Sample pictures of Echocardiogram after Brightness adjustment and Histogram Equalization process

2.2 Edge Detection Algorithm

After the image improvements from the earlier steps, Edge Detection Algorithm was applied through Sobel Compass Operator which is a set of matrix that, after Cross Correlation operation, can be used to distinguish the weight of the edge of the picture from other parts.

$$W_0 = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad W_1 = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix} \quad W_2 = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \quad W_3 = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad W_5 = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix} \quad W_6 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad W_7 = \begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$$

The picture was weighted in eight directions.

After that, Threshold was applied again to filter the color so that only two colors values left in the picture – 0 for the background and 255 for the object in the picture.

2.3 Endocardium Segmentation

2.3.1 Edge Pixel Searching

Apply Circle Algorithm to Search Algorithm (Edge Pixel Searching)

$$X_{new} = X_c + (Radius \times \cos(\text{angle}))$$

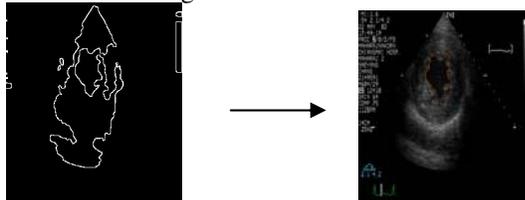
$$Y_{new} = Y_c + (Radius \times \sin(\text{angle}))$$

This procedure is Semi Automatic process to accept X_c , Y_c which are the center co-ordinates of the Endocardium because this co-ordinates can not be automatically pointed. The process started by finding the color value of pixels that are not equal to 0 then increase the radius by 1 until reach the MaxWindow number. If the MaxWindow number is reached without finding of the wanted color value or find it before reach MaxWindow number, the angle will increase by 1. After the value is found in each round of angle, it would be stored in the Edge list which is the list of the edge co-ordinates. However, there are gaps between each point so the Polyline algorithm is applied to connect the outline created the close area of contour with a specified color.

Then, after creating of the overall outline, the color pixel co-ordinates were collected in the Contour list to be used later to calculate for Scanline.

2.3.2 Contour Pixel Searching

After the use of Polyline algorithm to draw the Endocardium outline, the co-ordinates of the outline were collected by considering the pixels with the same color value to the contour color from the previous step to continue on drawing the overall outline.



Edge Detection

Endocardium Segmentation

Figure 7. & 8. Sample pictures of Echocardiogram after Edge Detection and Contour Pixel Searching process

3. Results

The sample used for the demonstration was collected from Echocardiogram device at the size of 480 by 512 pixels and was processed with the Threshold number of 18, Distance = +2, double increase of brightness, and 95 searching color pixels. After the demonstration, pictures were chosen according to its conditions and evaluated with Pearson Correlation Coefficient on the performance of the method. The results were presented here with the symbol R as the Correlation Coefficient and value of 'Error' to represent the difference between distance of the Endocardium contour line projected by manual track and auto track as shown:

Table 1. Correlation Coefficient and Error value between distance of the Endocardium contour line projected by manual track and auto track

	Manual Track	Auto Track	R	R ²	Error (pixel)
1			0.9147	0.8366	1.944
2			0.9615	0.9244	1.034
3			0.9864	0.9729	0.658
4			0.9406	0.8847	1.237
5			0.9271	0.8595	2.663
6			0.7697	0.5924	4.331
7			0.8593	0.7394	5.780
8			0.9373	0.8785	3.340
9			0.8647	0.7477	4.039
10			0.8949	0.8008	3.640
		Average	0.9057	0.8237	

From the demonstration, Correlation efficient of each picture ranged between 0.7 and 0.9 ($\bar{x}=0.9$) which shows good results and indicates that the contour lines projected by auto track and manual track are closely shaped. However, when considering the 'Error' value in some pictures, there are points that still give out the significant error in the pictures. Some pictures illustrate the minor mistakes while some others might have an unacceptable error of more than 20 pixels.

4. Discussion and conclusions

After the demonstration and application with multi-scanline procedure which is the objective of the study, the method showed good potentials and the obtained coordinates of the contour line can be used to create the multi-scanline. This created multi-scanline, which was plotted as a graph, helps the physicians to diagnose some evidence of heart disease by observation the distance of each scanline frame between diastolic and systolic period of the heart and the continuity of each frame. Some small errors can be neglected and have no effects on the plotted graph as it was considered to have little influences. The study also helps the physicians to learn about the suitable procedure to collect the picture for the best scanlines until they are satisfied.

Furthermore, it can be concluded that the constructed method is more suitable with the area of closed shape with no polygonal complexity. The most suitable picture is the one with clear edge in every direction which can be controlled and obtained during the collection stage of the picture. This method is also more appropriate in finding a rough picture of endocardium than to get the precision in pixel level and also not suitable yet in calculating the volume of the heart.

The computer used with the process also needs to be very efficient with the memory high enough for quick calculation.

Further work includes development of the program especially on the case with Polygonal complexity. Application of Artificial Intelligence such as Pattern Recognition can also be applied in the future to develop the algorithm on Edge Detection and Contour Pixel Searching for a more precise segmentation in every pattern of picture. Concerning the ease of use, the mechanism on parameters accepting should be improved or developed into a full automatic system. Also, Parallel algorithm might be utilized to improve the calculation speed of the work.

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