Improved Segmentation of Cardiac Image Using Active Shape Model

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***Abstract*— Cardiac is a center of body's function cause its role as blood pumping. Cardiac analysis done by observation the echocardiography result. Analyze do manually by doctor based on his viewpoint, accuracy and his experience, thus allowing each doctor have different analysis. Therefore, needed a system that can help the doctor to measure cardiac cavity area. This research will be develop a system that can measure cardiac cavity area. This system input used echocardiography video on the short axis view, next do the preprocessing to improving image quality and reduce the noise. Cardiac segmentation is done by using active shape model to tracking the cardiac cavity. After segmentation the cardiac cavity, then measure the cardiac cavity area with Partial Monte Carlo method. This research is expected to help the doctor to measure the cardiac cavity. Based on experimental result show that the errors of system is 4.309%**

Keywords— echocardiography, preprocessing, active shape model, monte carlo

I. INTRODUCTION

The performance of the cardiac is analyzed by the doctor through echocardiography (cardiac ultrasound), where analysis is done manually based on the physician's perspective and accuracy and experience. This makes it possible that every doctor will have multiple analyzes, making it difficult to determine the actual state of the cardiac [3]. Therefore we need a system that can measure the area between the cardiac wall as a determinant of normal cardiac decision-making or not.

Active Shape Models have been shown to be successful in many segmentation tasks such as left ventricle, prostate, brain, and lungs, recently the RV [4], diagnose and treatment of skeletal disease, extraction of lip contours to improve visual speech, shape variations analysis and reconstruction [5]. This methodology has proved to be competitive in several contexts, e.g., in lip and vehicle tracking, LV tracking in ultrasound (US) images, or other medical applications [6]. Some works have tried to improve the ASM by finding a combination of boundary points that best fits the expected segmentation [7]. ASM's detect the cardiac contour by minimizing an energy function that measures the difference between the model and image data [8]. An ASM based approach comprises two phases: 1) a training phase, in which the expected shape and variation of the LV are learned from training data; and 2) a test phase, in which the learned shape model is used to guide the segmentation of new data. In the latter, after initializing the model, candidate border points are extracted from the image and used to estimate the ASM parameters that fit the model to the desired border [9].

This research, create a system that can measured the cardiac cavity areas by using Active Shape Model method for tracking the movement of ventricle. Performed preprocessing using Median Filtering to reduce. Then, using Active Shape Model for segmentation and tracking. And the last, measure the areas of cardiac cavity by using Partial Monte Carlo method.

II. METHODOLOGY

To calculate the cardiac cavity, the procedure to be done is load video, do the preprocessing, segmentation and calculate the cardiac cavity. Figure 1 is a procedure of this system to segmentation and measure the area of cardiac cavity.

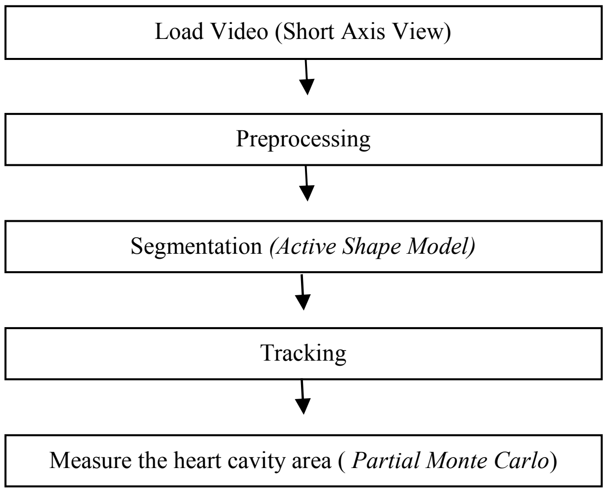

Fig. 1. System Diagram

A. Load Video

In shooting cardiac, there are some standard views of the cardiac cavity video, for example short axis, long axis [1], two chambers and four cambers views [2]. In this research, use the sort axis view from the left ventricle in echocardiography video. Figure 2 is a left ventricle of cardiac in short axis view.

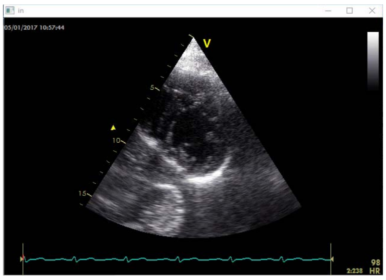

Fig. 2. Short axis view

B. *Preprocessing*

Echocardiography image have a lot of noise and should to enhance and improve the image quality with *preprocessing*. These are some steps for *preprocessing* :

1) *Median Filtering*

Median Filtering is a non linier method that effective to reduce the noise but still retaining edges. *Median Filtering* moving through pixel by pixel in an image, replacing each value with the median value of neighboring pixels. Median filtering is calculated by first sorting all pixel values from window to numerical sequence, an then replacinf pixels with pixel middle values. The *median filtering* formula can be representated as:

$$f(x,y) = \text{median}_{(s,t) \in S_{xy}} \{g(s,t)\}$$

result of *median filtering* process can be seen in a Figure 2

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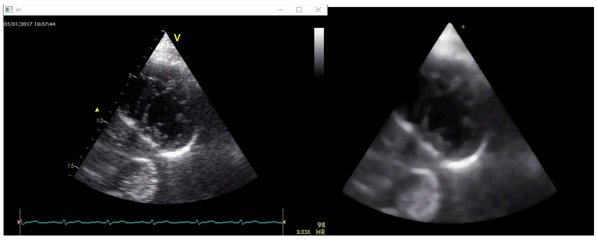


(a) (b)

Fig. 3. Comparison between input video with result of median filtering (a) Input Video (b) Median Filtering result

C. *Active Shape Model*

Active Shape Model are statistical models of the shape of objects which iteratively deform to fit to an example of the object in a new image. *Active Shape Model* have two steps, these are training and fitting.

1) *Training*

Training is a stage of extracting data and knowledge of training data. *Training* is the stage that will generate information from input data provided in accordance with the learning outcomes of the training phase. The steps of the *training* are can be represented by Fig 7.

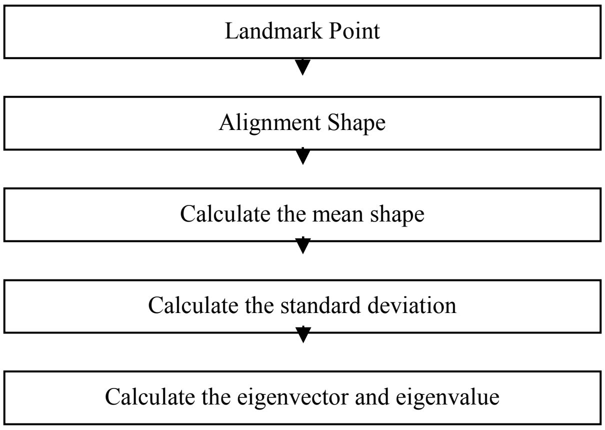


Fig. 4. Training steps

a) *Landmark point*

This step used for representation the shape into point. That point is called a "*landmark point*".

$$\tilde{x} = (x_1, y_1, \ldots, \ldots, x_n, y_n)$$

Fig 8. Is a result of landmark point from five videos.

Fig. 5. Landmark point

b) *Alignment Shape*

Landmark point have the difference position is too far, so we did the alignment to aligning to the first form. Aligning can be done by rotating and scaling. The formula can be represented as :

$$M(s,\theta)\begin{bmatrix} X_{jk} \\ Y_{jk} \end{bmatrix} = \begin{pmatrix} (s\cos\theta)X_{jk} - (s\sin\theta)Y_{jk} \\ (s\sin\theta)X_{jk} + s\cos\theta)Y_{jk} \end{pmatrix}$$

The alignment algorithm is as follows:

- Rotate and scale each shape to align with the first shape in set
- Repeat
  - Calculate the mean shape from the aligned shapes.
  - Normalize the orientation, scale and origin of the current mean to suitables defaults
  - Realign every shape with the current mean.
- Until the process converges [10]

c) *Mean*

In this section, calculate the mean shape from all of alignment shape data. The formula to calculate the mean shape as :

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$$

Figure 8 is a result of the mean shape from all of alignment shape.

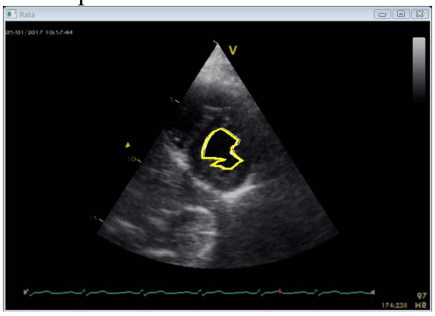


Fig. 6. Mean Shape

d) Standard Deviation

Standard Deviation is used to knowing the distribution of data in the sample, and to knowing how near the points to the mean. The formula can be represented as :

$$dx_i = x_i - \overline{x}$$

e) Covariance Matrix

Covariance is a size of how many the different of two sets data. *Covariance* determines the extent of related variable or how they vary together. The formula can be represented as :

$$S = \frac{1}{N-1} dx_i dx_i^T$$

f) Eigen Value and Eigen Vector

Eigen Vector used for projecting the data that have the biggest variation corresponding to the linier transformation of high –dimensional space to the low-dimensional space. *Eigen Value* is a representative part of the eigenvector. The formula can be represented as :

$$\mathrm{Sp}_k = \lambda_k \mathrm{p}_k, \lambda_k \geq \lambda_{k+1}$$

Table I is a result of eigenvalue from 10 frames.

TABLE I. RESULT OF EIGEN VALUE

FRAME-	EIGEN VALUE
5	[22.474848, 0; 4.91431, 0; 2.8901708, 0; 0.61906779, 0; -4.8983984, 0]
20	[58.759632, 0; 6.5686531, 0; 3.6230459, 0; -3.6719167, 0; -8.2794161, 0]
35	[32.046425, 0; 8.1649609, 0; 3.0577545, 0; -3.2574003, 0; -17.011742, 0]
50	[35.55481, 0; 4.6726127, 0; 2.0172834, 0; -0.27581942, 0; -1.9688886, 0]
65	[55.90789, 0; 8.7565289, 0; 1.4542114, 0; -1.7749746, 0; -12.343657, 0]
80	[31.632256, 0; 9.5054741, 0; 3.4946401, 0; 0.52146822, 0; -5.1538363, 0]
95	[54.473759, 0; 7.704134, 0; 1.4772032, 0; -3.8312337, 0; -15.823866, 0]
110	[21.319647, 0; 12.212904, 0; 5.4346228, 0; 0.98525047, 0; -1.9524201, 0]
125	[45.646206, 0; 7.4202857, 0; 2.7680061, 0; 1.5719664, 0; -5.4064684, 0]
140	[12.462653, 0; 6.2510538, 0; 3.009717, 0; 0.37584886, 0; -2.0992727, 0]
MEAN	[3.21007538e+001, 1.50000006e-002, 7.41367722e+000, 0., 3.29627228e+000, 0., 2.34205350e-001, 0., -4.36491013e+000, 0.]

2) Fitting

In this section, *Fitting* is used to fit the mean shape result according to the new image. An shape in the training set can be approximated using the mean shape and a weighted sum of these deviation obtained from the first t modes[10]. The *Fiting* formula can be represented by :

$$x = \overline{x} + Pb$$

Where P = $(p_1, p_2, \ldots p_t)$ is the matrix of the fisrt t eigenvectors, and b = $(b_1, b_2, \ldots, b_t)^T$ is a vector of weights.

3) Monte Carlo

Monte Carlo is used to calculate the cardiac cavity area. Calculation of the cardiac cavity done by generate the random samples, then calculate the sample ratio between samples in the segmented area (nd) with total number of samples (ns). Monte Carlo formula can be represented as :

$$Area = nd/ns * (MaxX - MinX) * (MaxY - MinY)$$

Partial Monte Carlo is part of Monte Carlo algorithm. The purposed of this algorithm is to improve calculation faster than normal Monte Carlo. The idea is to divide the region boundary in several sections and search box in the area of the boundary [1]. Fig 10 is a implementation of the *Monte Carlo*.

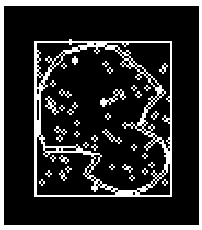
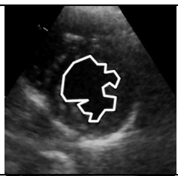
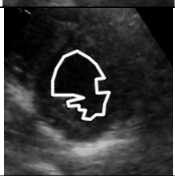
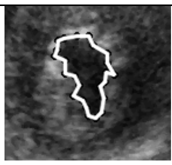
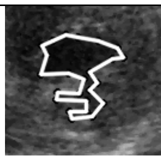
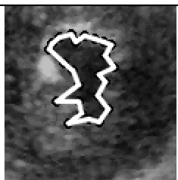
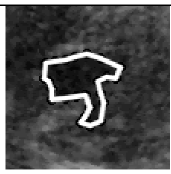
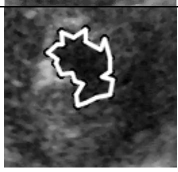


Fig. 7. Partial Monte Carlo with 100 random points

III. EXPERIMENTAL RESULT

In this section, will be explained about the final result of the system. the input data from Dr. Soetomo Surabaya. This input using echocardiography video in short axis view. Table III, IV, and V is the area comparison between manual segmentation and using *Active Shape Model Method*. Table II show the segmentation process of the video. On testing this system we tried with three different videos.

TABLE II. FITTING PROCESS

Frame	A	B	C
0			
5			
10			
15			
19			

Based on table II, can be seen that segmentation result with active shape model result already has detected the cardiac cavity well.

After doing the segmentation, then do find contour to get the value of minX, maxX, miinY and maxY from the contour as a limitation for random points.

TABLE III. TESTING OF RANDOM POINTS

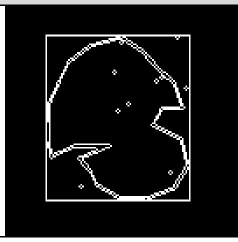
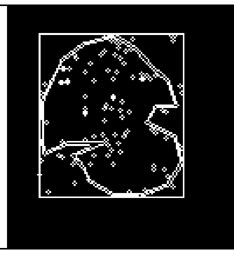
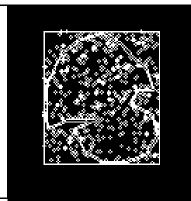
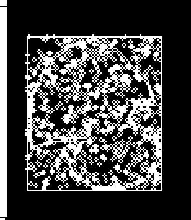
RANDOM POINTS	IMAGE
10	
100	
500	
1000	
10000	

Table III shows that the distribution of random point from 10 points, 100 points, 500 points, 1000 points, and 10000 points. From its we know that 10000 points is the most stable distribution, so we use 10000 random points to calculate the cardiac cavity.

TABLE IV. AREA CALCULATION VIDEO I

FRAME	METHOD (MM^2)		ERROR (%)
	MANUALLY	ASM	
0	1464	1420	3.005464481
1	1455	1302	10.51546392
2	1390	1349	2.949640288
3	1199	1208	0.750625521
4	1187	1201	1.179443976
5	1150	1171	1.826086957
6	1124	1100	2.135231317
7	1104	1114	0.905797101
8	932	913	2.038626609
9	927	939	1.294498382
10	779	784	0.641848524
11	720	728	1.111111111
12	638	633	0.78369906
13	599	588	1.83639399
14	576	562	2.430555556
15	535	543	1.495327103
16	528	597	13.06818182
17	580	598	3.103448276
18	502	498	0.796812749
19	466	453	2.789699571
MEAN			2.732897815

TABLE V. AREA CALCULATION VIDEO II

FRAME	METHOD (MM^2)		ERROR (%)
	MANUALLY	ASM	
0	1633	1431	12.3698714
1	1532	1488	2.872062663
2	1273	1297	1.885310291
3	1326	1235	6.862745098
4	1144	1154	0.874125874
5	1041	1033	0.768491835
6	741	861	16.19433198
7	879	746	15.13083049
8	726	765	5.371900826
9	626	677	8.146964856
10	590	581	1.525423729
11	516	523	1.356589147
12	490	460	6.12244898
13	527	462	12.33396584
14	398	387	2.763819095
15	512	418	18.359375
16	377	410	8.75331565
17	441	391	11.33786848
18	462	421	8.874458874
19	376	410	9.042553191
MEAN			7.547322666

TABLE VI. AREA CALCULATION VIDEO III

FRAME	METHOD (MM^2)		ERROR (%)
	MANUALLY	ASM	
0	1085	960	11.52073733
1	994	943	5.130784708
2	968	930	3.925619835
3	1183	1071	9.467455621
4	1090	1001	8.165137615
5	1032	912	11.62790698
6	984	941	4.369918699
7	971	950	2.162718847
8	900	873	3
9	872	867	0.573394495
10	687	664	3.347889374
11	615	609	0.975609756
12	523	497	4.971319312
13	457	462	1.094091904
14	360	353	1.944444444
15	439	448	2.050113895
16	320	348	8.75
17	287	306	6.620209059
18	318	372	16.98113208
19	337	332	1.483679525
MEAN			5.408108173

TABLE VII. AREA CALCULATION VIDEO IV

FRAME	METHOD (MM^2)		ERROR (%)
	MANUALLY	ASM	
0	1884	1761	6.52866242
1	1769	1741	1.58281515
2	1844	1817	1.464208243
3	1765	1710	3.116147309
4	1586	1570	1.008827238
5	1574	1420	9.783989835
6	1359	1317	3.090507726
7	1286	1267	1.477449456
8	1278	1281	0.234741784
9	1154	1141	1.126516464
10	1069	1013	5.238540692
11	1017	1001	1.573254671
12	1006	977	2.882703777
13	947	944	0.316789863
14	925	872	5.72972973
15	876	859	1.940639269
16	869	833	4.14269275
17	913	843	7.667031763
18	925	869	6.054054054
19	804	782	2.736318408
MEAN			3.38478103

TABLE VIII. AREA CALCULATION VIDEO V

FRAME	METHOD (MM^2)		ERROR (%)
	MANUALLY	ASM	
0	1959	1949	0.510464523
1	2009	1998	0.547536088
2	1926	1907	0.986500519
3	1775	1730	2.535211268
4	1820	1749	3.901098901
5	1754	1677	4.389965792
6	1479	1350	8.722109533
7	1219	1215	0.328137818
8	1178	1201	1.9524618
9	897	916	2.118171683
10	811	782	3.575832306
11	791	793	0.252844501
12	762	756	0.787401575
13	678	685	1.032448378
14	691	686	0.723589001
15	696	728	4.597701149
16	728	734	0.824175824
17	783	764	2.426564496
18	813	807	0.73800738
19	861	788	8.478513357
MEAN			2.471436795

Based on Table IV, V, VI, VII and VIII the area calculation between manual segmentation and ASM segmentation have a small value differences. Active Shape Model can do segmentation well. Based on table IV, V, VI, VII and VIII the error is 2.733%, 7.547%, 5.408%, 3.385 and 2.471%. So, the system assessment has 4.309% errors.

IV. CONCLUSION

The purposed of making this system is for segmentation the cardiac cavity then calculate the area to knowing the cardiac performance. Preprocessing to enhancement and improve the image quality using Median Filtering, erosion, and dilation. The segmentation using Active Shape Model. Then to calculate the area using Partial Monte Carlo. This system has a 4.309% errors.

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