Heart Video Tracking System On Long Axis View

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***Abstract*—The heart is one of the vital organs in the body, Cardiac performance can be analyzed by a doctor through a cardiac examination with tests echocardiography (heart ultrasound), which usually contains information about the heart movement. One of parameter used in the analysis is the distance between the walls of the heart. The analysis results of the heart condition based on the echocardiography video is depend on accuracy and experiences of the doctor. This condition has a risk of differences the analysis results between doctors so that can causing patients confuse with their health status. This study was conducted to address the differences in diagnosis because of misreading of a heart condition in a video echocardiography. The system built in this study is to search the distance between the wall of the cardiac motion on echocardiography video parasternal long axis (PLAX) are semi-automatic. Histogram equalization, bilateral filter, and median filter are used to improve image quality. Bilateral filter Method is a filter that has three parameters calculation, which is based on the diameter, intensity of the color and depth range. After that, distance features is search using optical flow farneback, the farneback method will process all pixels in an image with a specific range of pixels to obtain higher accuracy. Farneback methods typically used to search for patterns of common movement objects, such as the movement of people and cars, but on the system is to see the pattern of heart cavity movement. Based on the experimental results of this study, conducted comparative measurements of the distance between the walls of the heart using this system and the manual way. Error obtained: 4,09% for the left ventricle, 4,37% for the aorta, and 3,59% for the left atrium.**

Keywords—echocardiography, PLAX, bilateral filter, optical flow farneback, distance feature

I. INTRODUCTION

Heart is a vital organ in the body that serves as the blood pumping. If the performance of the heart is abnormal, it can cause heart disease or more fatal is the death of the patient. In analyzing the performance of the heart, doctors usually perform observations of the test results echocardiography (heart ultrasound). Video results of echocardiography is the information about the movement of the heart, and this information can only be read by doctors. So that the analysis results on the circumstances of cardiac echocardiography video only rely on the accuracy and physician experience. This may cause the results of the analysis are different from each doctor and makes it difficult to determine the actual state.[1]

To solve these problems, in this research the systems is made for treating cardiac image on echocardiography's video to detect the movement cavity of heart. There are several process : preprocessing to improve the image, segmentation to search features and utilizing optical flow farneback to look for movement of the feature. Video input is used echocardiography video long axis view (PLAX). The resulting output is the distance between the walls in the cavity of the left ventricle, left atrium and aorta.

II. PREPROCESSING

In the preprocessing step is to produce clearer images, because the video echocardiography that there still have a lot noise so it will be a little disrupting existing processes. In this system, the results will produce the image preprocessing threshold as a result of segmentation is used for the search feature. Stages of preprocessing is started from histogram equalization which serves to flatten the value of gray, bilateral filter is used to smooth the image but still retains the structure of the edge image, median filter to reduce image noise and produce a threshold segmentation. The sequence of preprocessing can be seen in Fig.1.

A. Histogram Equalization

Histogram equalization is a process of flattening the histogram, where the distribution of the value of the degrees of gray in an image made flat. Working concept of histogram equalization is to change the distribution of the histogram value to obtain a histogram is evenly spread of values, so that each degree of gray has a relatively equal number of pixels. The algorithm of histogram equalization can be explained in the following steps:

- Calculate the histogram H to the input image (source)
- Normalize histogram so that the number of histogram is a maximum of 255 or maximum value based on the intensity of the image
- Calculate the integral of the histogram :

  $$H_i^{'} = \sum_{0 \le j < i} H(j) \quad (1)$$

- Change the image using H' like equation (2)

  $$dst(x,y) = H^{'}(src(x,y)) \quad (2)$$

  Where is dst as output image and src as input image
- This algorithm to normalize the brightness and increase the contrast of the image

B. Bilateral Filter

Bilateral filter method is a method of image quality improvement of non-linear adaptive. Bilateral filter method uses two kinds of weighting to the pixels in the image so as to produce a more accurate calculation than the previous methods, for example methods median filter and average filter (which will be compared to the results in this study). The weight of the first method is the weight of spatial bilateral filter, which calculates the proximity of pixels geometrically, while the second weight is the weight of photometric measure the difference in color intensity between the pixels in the image. Both of these weight calculation will produce an effective weight value due to take into account the proximity of the spacing between the pixels and color intensity differences between pixels.

C. Median Filter

Median filter is a method that focuses on the mean value of the total number of pixels that the overall value around it. Median filter is a filter that serves to soften the image and reduce the image noise or interference. To search for a median of the data set is odd then:

$$x = \frac{n+1}{2} \quad (3)$$

From what is described above, the result of a preprocessing step that starts from the histogram equalization, bilateral filter and median filter to the image segmentation results is threshold can be seen in Fig.1.

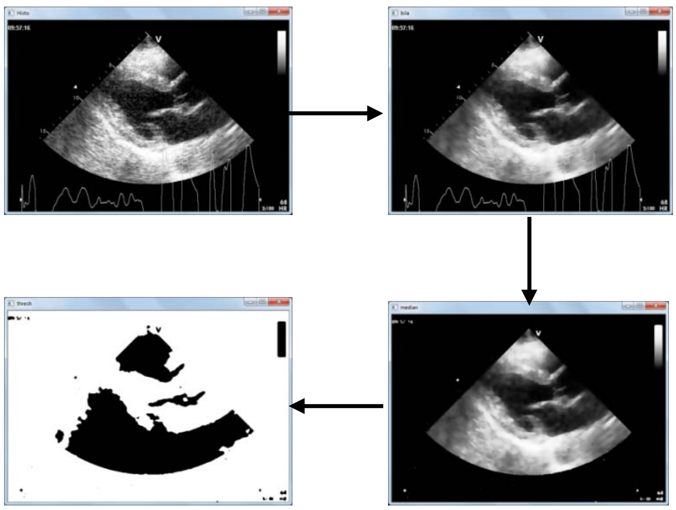


Fig.1.Preprocessing and segmentation result process

III. Feature Detection

Features used in this system is the position of the point. From the two points that are found to be a straight line. The straight lines represent the distance value in long axis of the heart cavity to be counted. The heart cavity is left ventricle, aorta and left atrium. Overview of the system for search features is shown in Fig.2.

Detection feature utilizing the linier equation based image segmentation results in the form of image threshold. Linier equation will help find suitable features from the route of the line segment that has been drawn before. To clarify how algorithm how to locate the position of the feature will be explained by measures such as the one below:

- The first step is to detect the color at the point (x1, y1) on the line segment that has been formed
- Then calculate the value of the gradient to determine the slope of the line in question, the gradient can be calculated by the following formula

  $$m = \frac{y_1 - y_2}{x_1 - x_2} \quad (4)$$

- Search the value of x using linear equation

  $$y - y_1 = m(x - x_1) \quad (5)$$

  From the equation above can be converted into the formula below to get the x value .y value is equal to $y_1 + 1$, this is because you are looking for is new coordinates after a coordinate (x_1, y_1).

  $$x = \frac{y_1 - y - m.x_1}{m} \quad (6)$$

- After finding the value of x, it automatically has also found new coordinates (x, y) and subsequently detected color at that point
- Compare the color in the new point to the previous point, if different then stored as one coordinate feature
- This process continues until it reaches the value of y = y_2.
- If the coordinates of the second feature has been found it will draw a line using the function line between the first point and the second point.

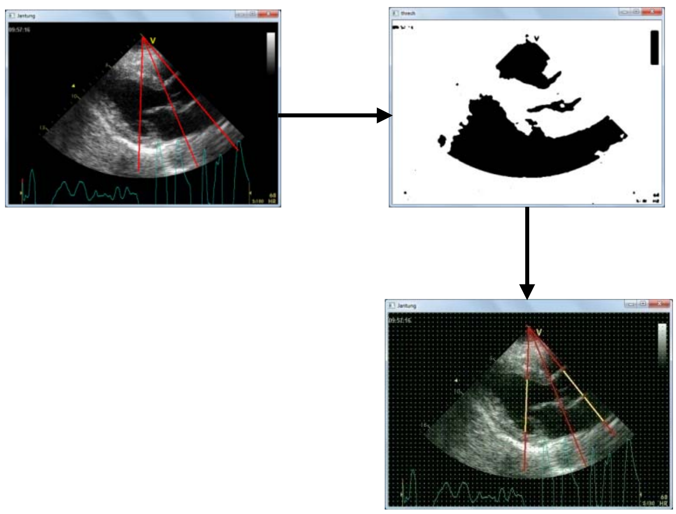


Fig.2.Feature detection flow diagrams

IV. Optical Flow Farneback

Optical flow is the patterns movement of objects, surfaces and edges in a visual scene caused by the relative motion between the seat (eye or camera) and real events. Optical flow is used to determine the displacement of the position of a pixel of the first frame to the second frame and into the next frames. Previous frame will go through the process as a bilateral filter reduces phase noise, it can help produce better optical flow. In this system a given point on the entire area of the image to be searched displacement movement on every frame. The greater the movement will produce a long line, whereas if the smaller the movement will produce a line short or no lines drawn at all. This line will represent the direction of movement of each point of the existing features. There are several lines of color spread in a single frame. Green indicates a feature that will be searched movement. Red indicates the direction of movement of the green features. The yellow color shows the movement of the initialization feature is done using a mouse. There are three parameters chosen yellow color to look for movement, namely the line to the left ventricular cavity, the line to the aorta and the line to the left atrium.

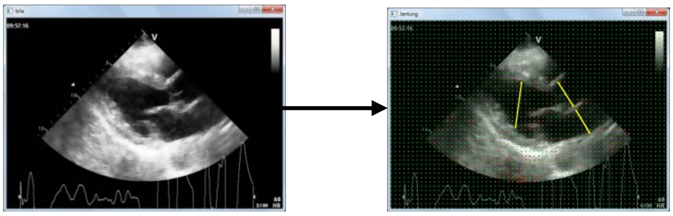


Fig.3.One result of optical flow farneback

V. DISTANCE

The output of the system is distance. Distance is generated from the line formed of the features that have been in the form of point coordinates in get. There are three parts to be counted, for the example is the distance on the left ventricle, aorta and left atrium. The distance will be calculated using the distance between two points is commonly called Euclidian distance. The following is the euclidean distance formula:

$$\boldsymbol{distance} = \sqrt{(\boldsymbol{x_2} - \boldsymbol{x_1})^2 + (\boldsymbol{y_2} - \boldsymbol{y_1})^2} \ldots\ldots\ldots\ldots\ldots (7)$$

The value of x and y for value range based on the new coordinate of the calculation of the equation 3.

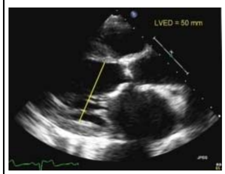
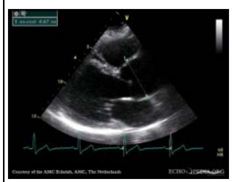
Each part of the heart cavity has a different way of measurement. In taking the distance of each cavity have different criteria, as well as the value of the resulting measure different distances. Distance measurement in left ventricular end systolic and done during late diastole. Weights and measures is to draw a parallel between interventricular septum (IVS) and posterior wall (PW). Selection of the location of the point on the posterior wall (PW) is below the mitral valve, between the wall and the pericardium. While laying points on the septum is near the aortic valve orifice [8].

The next distance measurement used in long axis view is in the left atrium and is commonly used measurement of left atrium anteroposterior (AP). The distance calculation for left atrium when the left ventricle must be done in the final state systole. The point is taken from the wall of the aorta posterior to the posterior wall (PW). Measurements were made perpendicular to the aortic root [8] [12].

Measurement of the aortic root can be done on video echocardiography parasternal long axis view (PLAX), because these views can describe the aortic root to the proximal ascending aorta. Measurements of the aorta should be done at the end of systole [8].

Here is a table of how decision-distance as well as a range of values within normal at each heart cavity parasternal long axis view:

TABLE 1. Reference measurement of the heart.

Cavity	Measurement	Diameter	Size (mm)	
			Men	Woman
Left Ventricle	 (source : web.stanford.edu)	Diastol	42.0 – 58.4	37.8 – 52.2
		Sistol	25.0 – 39.8	21.6 – 34.8
Aorta	 (source : echopedia.org)	Sistol	22 - 36	
Left Atrium	 (source : web.stanford.edu)	Sistol	26.4 – 42.3	24.4 – 38.5

VI. EXPERIMENTAL SETUP

The system is tested to see how big the error and test the validity of the system. The output of the system was largely the distance between the searches of the cavity. There are four tests, the first test is to see the accuracy of optical flow, the second test is testing manual method with several users, the third test is a accuracy comparison between two methods of optical flow, Farneback method and Lucas Kanade method. Last testing is a comparison system that uses optical flow farneback with reference value. Testing manually retrieve data from four different user and the results will be compared with the output of the system, will be shown in Table 6, 7, and 8. There are also testing the validity of optical flow by comparing the first and last frame of one phase of the heartbeat and the result table will be shown in table 2.

TABLE 2. Testing of optical flow.

		Initial Frame		Final Frame		Separation Distance	
		x	y	x	y	Pixel	mm
Left Ventricle	Point 1	305	151	304	150	1,41	0,56
	Point 2	296	238	295	238	1	0,4
Aorta	Point 3	389	139	390	139	1	0,4
	Point 4	425	190	429	187	5	2
Left Atrium	Point 5	435	204	439	201	5	2
	Point 6	464	247	464	247	0	0

Optical flow Testing results are shown in Table 2, aims to understand the shift from the initial frame until the final frame. The Test was done in one phase of the heartbeat. Coordinate value which is recorded is calculate using Euclidean equation. So that it can be seen how far the shift or the amount of error using optical flow farneback. Point 1 is located on the wall of the left ventricle, point 2 is located on the bottom wall of the left ventricle, point 3 is located on the upper wall of the aorta, point 4 is located on the bottom wall of the aorta, point 5 is located on the upper wall of the left atrium and point 6 is located on the bottom wall of the atrium left.

The second test is manual testing. The testing phase is done with initialization feature manually by several users. feature Initialization manually is using a mouse click on any cavities of the heart. It is to search the value of distance. The result of manual testing will be compared with the result of full system, that is to test the accuracy of the output on the system and output from the feature initialization manually.

TABLE 3. Manual testing on left ventricle.

Frame	A1	A2	A3	A4	Mean
7	52,4	55,2	56,8	55,3	54,92
20	52,9	52,9	50,7	52,3	52,2
29	47,8	48,7	47,6	45,7	47,45
40	51,5	51,4	48,2	49,6	50,17
48	57,4	55,2	52,8	56,4	55,45
55	50,4	54,3	53,3	54,2	53,05
63	47,5	47,2	45,9	46,7	46,82
71	43,4	42,7	43,4	38,6	42,02
83	55,3	53,9	52	52,8	53,5
97	57,1	52,5	51,9	53,7	53,8

TABLE 4. Manual testing on aorta

Frame	A1	A2	A3	A4	Mean
7	30,7	29,6	30,8	31,8	30,72
20	27,6	27,7	29,2	30	28,62
29	29,4	26,7	27,5	27,7	27,82
40	29	30,4	30,6	29	29,75
48	32,2	29,6	31,2	30,9	30,97
55	29	29,7	28,9	27	28,65
63	28,7	31,7	29,7	29,3	29,85
71	29,6	31,3	28,7	20,7	27,575
83	31	31,7	32	31,3	31,5
97	29,6	29,7	26,9	30,3	29,125

TABLE 5. Manual testing on left atrium.

Frame	A1	A2	A3	A4	Mean
7	28,2	28,8	26,5	25,6	27,27
20	27	29,1	25	25,6	26,67
29	29,9	29,1	29,1	28,4	29,12
40	27,3	28,3	26,4	26,9	27,22
48	27,8	29,5	29,3	26,6	28,3
55	26,8	25,5	24,5	26	25,7
63	24,2	26,3	26,1	26,2	25,7
71	26,5	28,9	24,9	25,8	26,52
83	24,4	29	25,6	26,9	26,47
97	24,4	22,9	24,8	26,2	24,57

On Table 3, 4 and 5, the variables A1, A2, A3, and A4 is naming to the user manual testing. From the results of the data in the table above can be seen the average value of measurements made by the four user. The average value is compared with the value of the system to produce an error value. This Error is caused due to user perception is different when see the image on echocardiography. In addition, factors that are less consistent video quality makes it difficult by the human eye to analyze the video .

The third test is to compare optical flow Farneback method is used on systems with optical flow Lucas Kanade method. This test aims to demonstrate the accuracy of the performance results of the two methods of optical flow. Tests will be done by comparing mean of the manual testing result with the results of both methods of optical flow.

TABLE 6. Comparing two method for measurement on left ventricle.

Frame	Mean	Farneback	Error	Lucas Kanade	Error
7	54,92	52,27	5,07	43,73	25,58
20	52,2	52,27	0,13	44,79	16,54
29	47,45	48,45	2,06	40,88	16,07
40	50,17	53,93	6,96	43,26	15,97
48	55,45	55,64	0,34	45,4	22,13
55	53,05	56,08	5,40	46,22	14,77
63	46,82	50,41	7,11	43,33	8,05
71	42,02	44,07	4,64	38,01	10,54
83	53,5	49,62	7,81	45,3	18,1
97	53,8	53,05	1,41	40,74	32,05
		Mean Error	4,09	Mean Error	17,98

TABLE 7. Comparing two method for measurement on aorta.

Frame	Mean	Farneback	Error	Lucas Kanade	Error
7	30,72	31,5	2,46	26,17	17,38
20	28,62	31,21	8,28	26,73	7,07
29	27,82	28,79	3,35	26,87	3,53
40	29,75	28,97	2,69	25,21	18
48	30,97	29,88	3,66	26,11	18,61
55	28,65	29,89	4,14	25,36	12,97
63	29,85	30,53	2,22	26,32	13,41
71	27,575	28,98	4,84	24,6	12,07
83	31,5	29,24	7,72	24,89	26,55
97	29,125	27,9	4,39	24,94	16,760
		Mean Error	4,37	Mean Error	14,63

TABLE 8. Comparing two method for measurement on left atrium

Frame	Mean	Farneback	Error	Lucas Kanade	Error
7	27,27	28,82	5,36	23,8	14,57
20	26,67	28,28	5,67	22,43	18,9
29	29,12	30,78	5,37	24,35	19,58
40	27,22	29,01	6,15	26,76	1,71
48	28,3	27,89	1,47	26,4	7,19
55	25,7	25,51	0,74	24,51	4,85
63	25,7	25,44	1,02	24,56	4,64
71	26,52	27,89	4,89	28,72	7,66
83	26,47	27,01	1,98	28,44	6,92
97	24,57	23,78	3,34	27,2	9,66
		Mean Error	3,59	Mean Error	9,57

In table 6,7, and 8 is the result of a comparison of the value of manual testing with Farneback method and Lucas Kanade method. This system which uses optical flow Farneback have error value less than 5% in the measurement of the whole heart cavity on long axis view, the cavity of the left ventricle, aorta and left atrium. Optical flow Lucas Kanade method applied in this system is not running well, because it has a fairly large error is 17.98% for the measurement of the left ventricular cavity, 14.63% for the measurement of the aorta and 9.57% for measurements in left atrium.

The fourth testing is comparing the results of testing the system with a reference value. In calculating the distance of the heart cavity are different criteria between women and men. Heart cavity of women-owned small if compared with the heart belong to man. Moreover, because each person has a heart size is different, and therefore the reference value for a healthy heart condition has a value range. The system is also tested for heart video 5 women and 5 men video heart.

TABLE 9. Testing diastole on the left ventricle of men.

VIDEO	Diastole Left Ventricle		
	Reference	Testing	Result
AO4	42,0 – 58,4	51,92	Success
AO17		46,17	Success
AO62		39,96	Not success
AO64		43,63	Success
AO25		44,99	Success

TABLE 10. Testing systole on the left ventricle of men.

VIDEO	Systole Left Ventricle		
	Reference	Testing	Result
AO4	25,0 – 39,8	36,63	Success
AO17		31,92	Success
AO62		31,07	Success
AO64		37,46	Success
AO25		32,95	Success

TABLE 11. Testing Aorta men.

VIDEO	Aorta		
	Reference	Testing	Result
AO4	22 - 36	29,13	Success
AO17		23,25	Success
AO62		20,61	Not success
AO64		24,49	Success
AO25		18,97	Not success

TABLE 12 Testing on the left atrium of men.

VIDEO	Left Atrium		
	Reference	Testing	Result
AO4	26,4 - 42,3	26,62	Success
AO17		24,49	Not success
AO62		36,57	Success
AO64		36,26	Success
AO25		30,76	Success

In addition to testing the echocardiography men video, the system was also tested in woman echocardiography video. Testing will be conducted on 5 women video echocardiography, and here are the results of testing that has been done.

TABLE 13. Testing diastole on the left ventricle of woman

VIDEO	Diastole Left Ventricle		
	Reference	Testing	Result
AO4	37,8 – 52,2	47,4	Success
AO17		46,61	Success
AO62		43,64	Success
AO64		40,72	Success
AO25		52,64	Not success

TABLE 14. Testing systole on the left ventricle of woman

VIDEO	Systole Left Ventricle		
	Reference	Testing	Result
AO4	21,6 - 34,8	38,84	Not success
AO17		31,99	Success

AO62		37,3	Not success
AO64		24,64	Success
AO25		38,14	Not success

TABLE 15. Testing aortas for woman.

VIDEO	Aorta		
	Reference	Testing	Result
AO4	22 - 36	20,88	Not success
AO17		24,95	Success
AO62		18,51	Not success
AO64		27	Success
AO25		21,11	Not success

TABLE 16. Testing on the left atrium of woman.

VIDEO	Left Atrium		
	Reference	Testing	Result
AO4	24,4 - 38,5	32,5	Success
AO17		32,72	Success
AO62		31,92	Success
AO64		20,15	Not success
AO25		30,65	Success

View from the overall testing performed on the video echocardiography with woman sex, there are some measurement that falls outside of the normal reference value. The failure could be due to the measurement of the heart is in unhealthy condition, and other causes is the system can not find the right features either. The most important thing is the process of finding the right position feature, it is influenced by the preprocessing stage segmentation results, and the depiction of a less precise location of pie will make the feature can not be found. Besides, the system is also affected by the lighting in the video, so that the system can not analyze the image well.

VII. Conclusion

Based on the experimental results, there are several factors that caused the system can't find the right position with the feature. Some of these factors is the use of parameter values both in the preprocessing stage or segmentation using threshold and the illumination of the video echocardiography is derived from the transducer position that is used by physicians during patient examinations. The movement of optical flow Farneback is restricted only 3 pixels to maintain the features remain in place and avoid any large movements. In addition, from the results of manual testing with system generates error 4,09% for the left ventricle, 4,37% for the aorta and 3,59% for the left atrium. While testing a system that compared with the reference value at 5 videos of men and 5 videos of woman with the amount of testing as many as 20 times (5 tests diastole of the left ventricle, 5 testing systolic of left ventricle, 5 testing of the aorta, and 5 testing of left atrium) results in males 16 was successful and 4 was not success, for females was 12 successful and 8 not success.

Reference

[1] Riyanto Sigit. (2014)."Segmentasi imej untuk video ekokardiografi menggunakan persamaan segitiga". Fakulti Kejuteraan Dan Alam Bina, Universiti Kebangsaan Malaysia Bangi.

[2] Saputro, Adhi Harmoko. (2013)."Penilaian Kuantitatif Analisis Ketakfungsian Ventrikel Kiri Secara Automatik Untuk Mengesan Penyakit Jantung Iskemik". Fakulti Kejuteraan Dan Alam Bina, Universiti Kebangsaan Malaysia Bangi.

[3] Slamet Riyadi. (2012)."Profil gerakan jantung berasaskan aliran optik", Fakulti Kejuteraan Dan Alam Bina, Universiti Kebangsaan Malaysia Bangi.

[4] Rahayuningsih, S. E. (2009, November). Recognizing the RV Anatomy by Echocardiography. In *Workshop on Echocardiography in Congenital Heart Disease*. Faculty of Medichine Padjajaran University.

[5] Farnebäck, G. (2003). Two-frame motion estimation based on polynomial expansion. In *Image analysis* (pp. 363-370). Springer Berlin Heidelberg.

[6] Selzer, A., M.D. 1992. Understanding Heart Disease. Berkeley: University of California Press:

[7] Iaizzo, P. A. 2005. *Handbook of cardiac anatomy, physiology and devices*. Totowa, New jersey: Press Inc.

[8] Lang, R. M., Badano, L. P., Mor-Avi, V., Afilalo, J., Armstrong, A., Ernande, L., ... & Lancellotti, P. (2015). Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and theEuropean Association of Cardiovascular Imaging. *Journal of the American Society of Echocardiography*, *28*(1), 1-39.

[9] Soesanto, A. M. (2011). Pengukuran Fungsi Sistolik Global Ventrikel Kiri. *Jurnal Kardiologi Indonesia*, *29*(2), 93-95.

[10] Baumgartner, H., Hung, J., Bermejo, J., Chambers, J. B., Evangelista, A., Griffin, B. P., ... & Quiñones, M. (2008). Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. *European Heart Journal-Cardiovascular Imaging*.

[11] Yuwono, B. (2015). Image Smoothing Menggunakan Mean Filtering, Median Filtering, Modus Filtering dan Gaussian Filtering. *Telematika*, *7*(1).

[12] Caballero, L., Kou, S., Dulgheru, R., Gonjilashvili, N., Athanassopoulos, G. D., Barone, D., ... & Hagendorff, A. (2015). Echocardiographic reference ranges for normal cardiac Doppler data: results from the NORRE Study. European Heart Journal - Cardiovascular Imaging, jev083.

[13] Evangelista, A., Flachskampf, F. A., Erbel, R., Antonini-Canterin, F., Vlachopoulos, C., Rocchi, G., ... & Breithardt, O. A. (2010). Echocardiography in aortic diseases: EAE recommendations for clinical practice. European Heart Journal-Cardiovascular Imaging, 11(8), 645-658.

[14] Claessens, T. (2006). *Model-based quantification of systolic and diastolic left ventricular mechanics* (Doctoral dissertation, Ghent University).