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To cite this article: Lina Farhana Mahadi *et al* 2019 *J. Phys.: Conf. Ser.* **1372** 012071

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Feature detection of mitral valve based on image processing technique: A review

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Abstract. Mitral valve prolapse is a standout amongst the most common heart conditions, which may influence up to five to 10% of typical populace and a standout amongst the most questionable ones. The advent of computer aided technologies has contributed widely in medical application. This paper discussed on a methodological study on medical image processing to evaluate accurate diagnosis in the field of computer vision. The fundamental of image processing is to enhance the raw images obtain from machine so the useful information can be extracted from it. This paper deals with the application of the image processing on mitral valve images for further research purpose. Ultrasound data taken with subject diagnosed by mitral valve disease is analyse to determine the diameter of the valve. Based on the experiment, the average of mitral valve diameter is 21.82 mm which represent the abnormal length of mitral valve for adult.

1. Introduction

The two chambers (atrium and ventricle) of the left side of the heart were separated by mitral valve. As the heart contract, the leaflets of the mitral valve bulge (prolapse) into the left atrium in mitral valve prolapse [1]. Mitral valve prolapse causes the leaking of blood from the ventricle into the atrium which known as Mitral valve regurgitation [2]. In this condition, the blood may flow in two directions during the contraction. Supposedly, the blood will flow from the ventricle through the aortic valve. However, in this case some of the blood will flow back into the atrium. Therefore, the blood volume and pressure in the area will increase due to the leakage. Ultrasound imaging has been widely used as one of diagnostic method. The information of the diagnosis of disease can be extracted by the image produce with high frequency sound wave. Ultrasound machines are non-invasive, low cost and save time, but it depends mostly on the operator's skills and experiences to capture clear images. Image processing is important in order to absorb value information within the image which including the operation of converting the image properties and perform some operation to enhance the image. Despite the measurement of blood flow velocity, researchers found that the study of the factor that trigger the velocity in heart is more reliable, which focus on valve patency behaviour [3]. The normal diameter of the mitral annulus is 2.7 to 3.5 centimeters, and the circumference is 8 to 9 centimeters [4]. The purpose of this article is to deal with echocardiographic assessment by the image processing on the mitral valve.

2. Related work

1.1. Image denoising

Noise is an undesired data present in an image which can be removed with filters. In digital image processing, filters can be connected to an image in two different ways, which incorporate spatial and frequency domain. Based on its nature, noise can be modelled as either an additive or a multiplicative process.

$$g(x, y) = f(x, y) + n(x, y)$$
$$g(x, y) = f(x, y) * n(x, y) \tag{1}$$

In image processing, filters can be categorized into convolution based, hybrid and order statistics filters [4]. Apparently, Wiener filters shows promising result in removing Gaussian as well as Poisson noise [5]. Moreover, Mean and Gaussian filters also perform well in removing Gaussian noise compared to median filters [3, 6]. In some cases, by using a frequency domain method, the wiener filter has been applied on noisy image which removed the Speckle, Poisson and Gaussian noise present in the image [8]. Other than that, WB-Filter for Medical Image denoising which is a combination of median filtering and bilateral Filtering is implemented in [7,9] to determine the best performance and comparability to the median, wiener and bilateral filters. In this filter each pixel in an image is replaced by a weighted average of intensity values from nearby pixels and second filter used to minimize the mean square error between estimated and the desired. Different remedies of median filters have been proposed, in the literature like, adaptive median filter [10], the multi-state median filter [11], median filters based on homogeneity information [12,13]. Due to its good denoising power [12] and computational efficiency, the median filter was the most popular non-linear filter for removing impulse noise. However, some details of the original image might be smeared by the filter during high noise levels. A new approach to identify pixels corrupted with salt and pepper noise has been proposed where the noisy pixels are replaced with median value in their vicinity [13]. The algorithm developed by [14, 16] was used to remove the noise and adjusting the contrast and image enhancement [15]. The result of applying these algorithms on a sample of echocardiography image is shown in the figure 1.
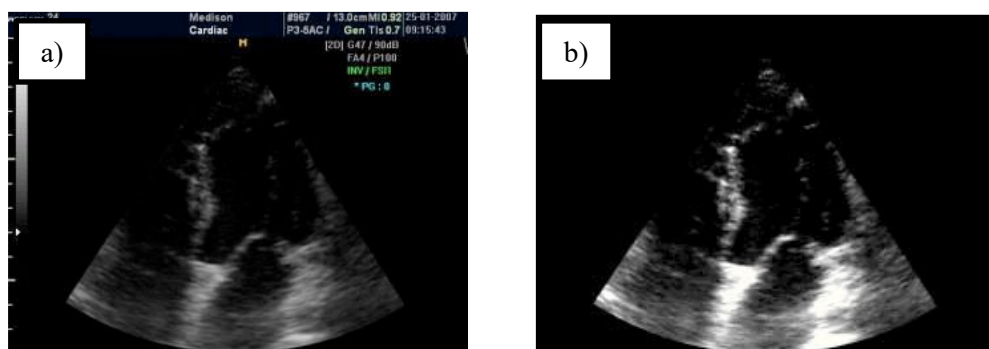

Figure 1. (a) Main input image (b) The result of using image enhancement

2.2. Image segmentation

Segmentation is the dividing of a picture into significant areas, most as often as possible to recognize items or locales of intrigue ("forefront") from everything else ("foundation"). In reference [22], the creator proposed the denoising strategy for medicinal pictures utilizing thresholding and streamlining utilizing a stochastic and randomized method of Genetic Algorithm. Thresholding is as indicated by the intensity/brightness is a basic strategy for pictures which contain strong articles on a foundation of various, however uniform, brightness. Every pixel is contrasted with the edge: if it worth is higher than the limit, the pixel is viewed as "frontal area" and is set to white, and on the off chance that it is not

exactly or equivalent to the edge it is considered "foundation" and set to dark. The accomplishment of thresholding depends fundamentally on the choice of a fitting edge [23-25].

3. Application in mitral valve detection

3.2. Sampling and image acquisition

Ultrasound images were obtained by the S5-1 sector probe, which was connected to ultrasonic diagnosis equipment Philips iE33, located in Medical Imaging Laboratory Pantai Hospital Klang. A subject who suffers from mitral valve disease was selected in this study. The images were scanned from the left parasternal window. The parasternal long axis (PLAX) appeared in figure 2 is acquired by putting the transducer in the three to four left intercostal spaces near the sternum with the beam arranged toward the patient's right shoulder. This direction cut through the heart on a long axis from base to apex. After collecting the video file from the ultrasound imaging system, the video file was extracted into frame image by using MATLAB and continue with image processing.

3.2. Image processing

In this study the region of interest is on the mitral valve. Therefore, we create fixed coordinate pixel to crop the original image to only view selected region. The colour image is then converted into grayscale to reduce the complexity from a 3D pixel value (RGB) to a 2D value which ranges between 0 to 255 (8-bit unsigned integers). The concept of unsharp masking is to remove a scaled blur version of the image from the original. The result appears to be a better and sharp image; crisper and clearly defined edges. The images then undergo more edge detection, skeletons to reduce all objects in an image to lines, without changing the essential structure of the image and finally finding the endpoint of the skeleton for further research purpose. The 3x3 images produce when undergoes overall image processing can be seen in figure 3.

3.3. Mitral valve diameter measurement

The diameter of the mitral valve is then being measured using 'imtool' in MATLAB software. The instrument indicates the separation in information units controlled by the XData and YData properties where the worth is gotten in pixel esteem, as a matter of course. To obtain the measurement in proper units, the pixel value has been manually calculated. The calculation to measure distance in millimeter (mm) is

$$(N \: / \: M) * 10 = A \: mm \tag{2}$$

since 1 centimeter (cm) = 37.795275591 pixel (X), where N is a measured pixel value from image, M is a pixel value for 1 cm in image and A is a measurement in distance (mm). In this section, the endpoint produced in the last step of image processing is being used for measurement of the mitral valve diameter. Note that the measurements are initially in pixel value before being converted into millimeters unit. The example of measurement in pixel on the endpoint of the skeleton image by using 'imtool' in MATLAB software can be shown in figure 4. The pixel region of the endpoint skeleton images is in binary.

The skeletonization is based on the thinning morphological operation. In binarized picture, pixels that are set to 1 distinguish local maxima; every other pixel are set to 0. Local maxima are related pieces of pixels with a reliable intensity value, and whose external cutoff pixels all have a lower value. Meanwhile, Table 1 shows the overall measurement result of the mitral valve in pixel and millimeter unit per frame and then converted into per time as shown in figure 5. The video taken was acquired in complete four beats of QRS complex wave which relates to the depolarization of the right and left ventricles of the human heart and compression of the huge ventricular muscles. However, the measurement of the mitral valve diameter in millimeter was calculated from frame image 4 until 36 which consisting 3 complete pulse waves considering the errors that might be perform before and after the data acquisition. Based on the graph in figure 5 it can be seen that the value of the diameter of mitral valve were fluctuated over frames due to systolic and diastolic of the heart. Originally, the images have

been extracted from the video to 25 image frames per second. Therefore, the video produced about 49 frame that is 1.96s. The diameter of mitral valve per time unit for this patient can be observed as shown in figure 5.
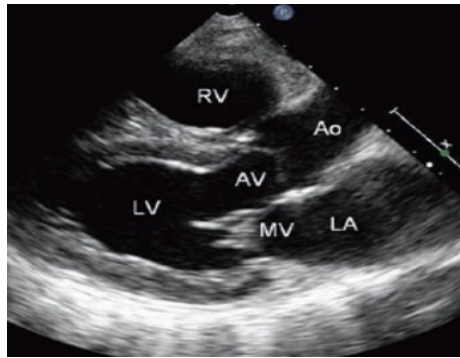

Figure 2. The parasternal long axis (PLAX) view. LA, RA, LV, and RV represent left/right atrium, and left/right ventricle, particularly, while MV and Ao is mitral valve and aorta.
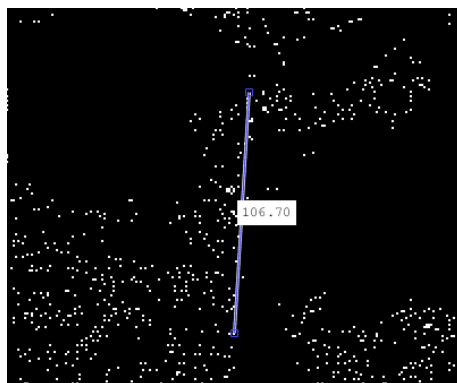

Figure 4. The mitral valve diameter in pixel unit distance using 'imtool' on endpoint of skeleton image.
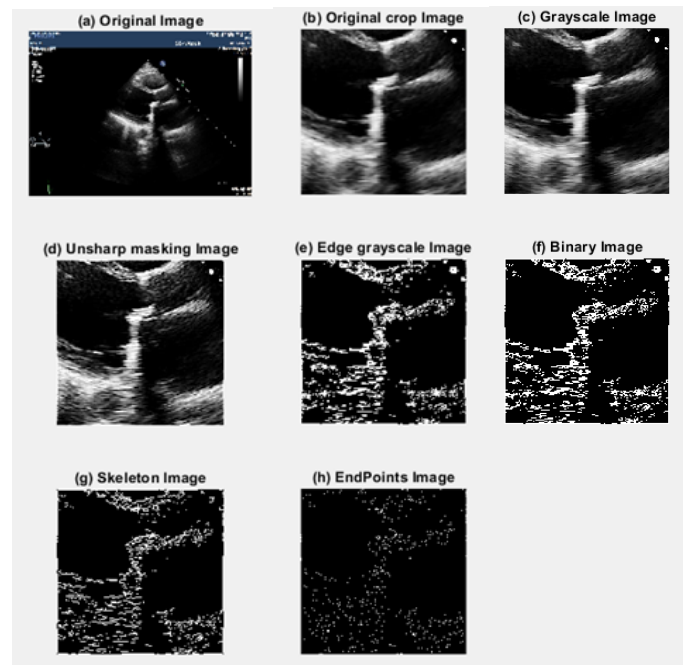

Figure 3. The images 3x3 produce in MATLAB software when undergoes image processing: (a) Original input image, (b) Region of interest, (c) Grayscale image, (d) Unsharp masking image, (e) Edge detection image, (f) Binary image, (g) Skeleton image, (h) Endpoints image.
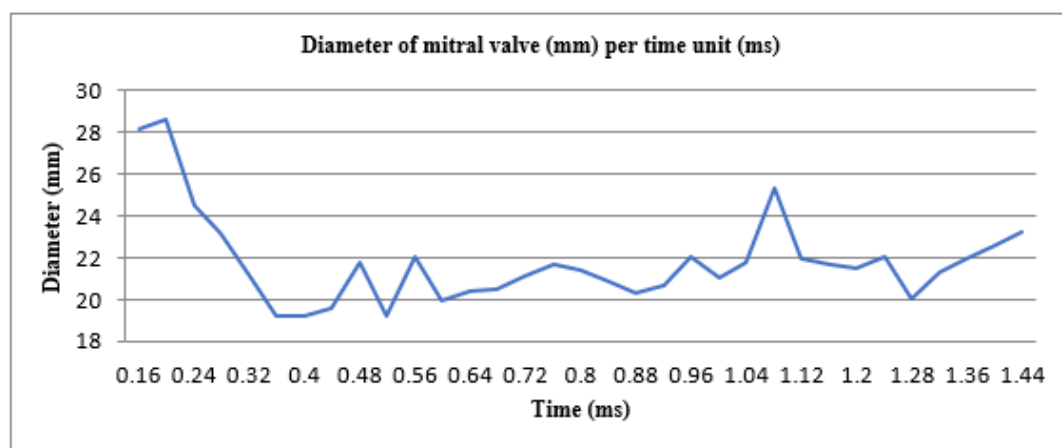

Figure 5. The mitral valve diameter per time unit

Table 1. The mitral valve diameter measurement in pixel unit

Frame images (n)	Pixel distance (X)	Frame images (n)	Pixel distance (X)
4	106.7	20	81.01
5	108.06	21	78.66
…	…	…	…
		36	87.89

Based on the previous research it is found that image processing is vital to ensure all the value information is being recorded. In this study, the mitral valve is being measured based on the video captured and divided into consecutive of image frames. The range of frame utilized is from four until 36. The result of the mitral valve diameter measurement obtained will be used to determine the size of the template for template matching process. Since the standard diameter of mitral valve annulus is 27 to 35 millimeters, it proves the mitral valve in the subject is abnormal since the average value obtained is 21.82 mm. This is one of the first few steps in order to create the optimum size of the template matching for tracking the mitral valve and hence monitoring the blood flow. This study may serve as guidelines purposes for future tracking method.

4. Conclusion

Cardiac diseases are a major health concern worldwide. In particular, useful information about the cardiac function can be extracted by analyzing of echocardiography sequences. However, echocardiographic images are difficult to analyze. In this paper, a relative study is done as a review of various methods of image processing for mitral valve disease detection. The testing on the application of several techniques in image processing has been by shown by the early study of mitral valve detection mentioned above. The diameter of the mitral valve is being calculated and the measurements are fluctuated over image frame. Based on the experiment, the average of mitral valve diameter is 21.82 mm which represent the abnormal length of mitral valve for adult. Hence this review will highlight new panoramas for developing more robust technique.

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