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Diagnosis of Cardiac Disorders using 2-D Echocardiographic Images and Tongue Features

Anu Reeby John[1]
Electronics & Communication Engg
Amal Jyothi College of Engineering
Kerala, India

Jose J Edathala[2]
Electronics & Communication Engg
Amal Jyothi College of Engineering
Kerala, India

Abstract: This project proposes an approach for the diagnosis of cardiac disorders from 2-D echocardiographic images and tongue features. The first part of the project comprises of collecting the dataset of echocardiographic images from the hospital that included both normal and infarct cardiac pathologies. Detailed cavity geometry and the position of the mitral valve were accessed using de-noising, binarization and edge detection techniques. Feature extraction was done using Sliding mask techniques and Gray Level Co-occurence Matrix. Finally artificial neural network has been trained as a classifier for the automatic detection of the heart valve disorders in the echocardiographic images. The second part of the project includes the collection of dataset of tongue and then the colour, texture and geometry features of the tongue images was extracted. Tongue is the sprout of the heart and the heart is the supreme monarch of all organs. Support vector machine is used as the classifier for diagnosing cardiac disorders based on the extracted tongue features. Accuracy is estimated in both the cases. The main reason underlying this study arises from the finding that if the heart valve annulus fails to properly connect with the leaflets, then the functioning of the heart may be compromised resulting in heart valve regurgitation.

Keywords: Cardiac disorders; echocardiographic images; artificial neural network; tongue features; support vector machine.

I. INTRODUCTION

The cardiac diseases have been tremendously increasing a lot in recent years. As the heart is an important part of a human body, the functioning of the heart is very important to be in regular. It has been reported that the percentage of heart failure will increase to 23.3 million by the year 2030 [2]. Heart failure is a major clinical problem. The cardiac cycle is a combination of two phases of the heart which is the systole and the diastole. The diastole is the process of blood filled into a chamber of the heart and the systole is the process of blood flowing out from the chamber of the heart.

The aim is to identify the states of the heart and the volume during the cardiac cycle function occurs. Left ventricle is considered for the project due to its importance in pumping the oxygenated blood (pure blood) to all parts of the body. This was done by identifying the anatomical information of the heart with the dataset of both the normal and infant cardiac pathology images of the heart. This extracts the information about the given image and also differentiates them under the two categories either the heart left ventricle is in the diastolic state or under the systole state [1]. For identifying this, the mitral valve position of the heart needs to be considered.

The heart is a muscular organ which pumps blood through the blood vessels of the circulatory system. The blood provides the body with oxygen and nutrients and also it removes metabolic wastes. The heart is divided into four chambers: upper left and right atria; and lower left and right ventricles. Commonly the right atrium and ventricle are referred together as the right heart and their left counterparts as the left heart. Blood normally flows one way through the heart due to heart valves, which prevent backflow. The heart is enclosed in a protective sac called the pericardium, which also contains a small amount of fluid. The right atrium receives deoxygenated blood from the body and the left atrium receives oxygenated blood from the lungs.

When these contract the blood is pushed into the ventricles, which pump to propel the blood to the lungs and the rest of the body. Heart and its chambers are shown in Figure 1.

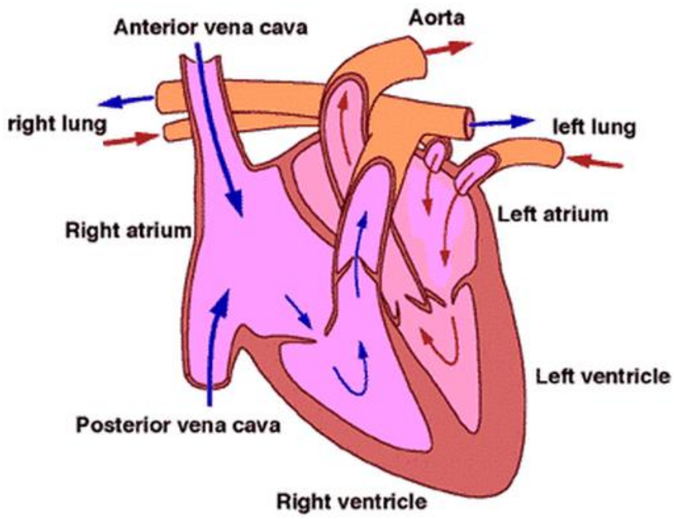

Figure 1 Heart and its Chambers

Echocardiogram is a sonogram of the heart. Echocardiography uses standard two-dimensional, three-dimensional, and Doppler ultrasound to create images of the heart. Echocardiography is commonly used in the diagnosis, management, and follow-up of patients with any suspected or known heart diseases. It is one of the most widely used diagnostic tests in cardiology. It can provide useful information mainly the size and shape of the heart, pumping capacity, and the location and extent of any tissue damage.

Tongue is a voluntary muscular organ. According to Traditional Chinese Medicine (TCM) tongue is connected to the internal organs of the human body. The tip of the tongue represents the heart and lungs, the central part represents the stomach and spleen, sides of the tongue represent liver and gall bladder and the root of the tongue represents kidney and bladder [5]. The partitions of the tongue and its relation with the internal organs [8], [9] are depicted in Figure 2. Nicolao et al. (2010) reported that the TCM practices such as acupuncture and physiotherapy are considered as the most popular disciplines requested by both medical experts and students in Switzerland [10]. In recent years it has received wider acceptance from western medicine.

The main aim of this project is to diagnose cardiac disorders using 2-D echocardiographic images and the tongue features (color, texture and geometry). Finally accuracy will be determined in both the cases. The disorders of mitral valve such as mitral valve regurgitation and mitral valve stenosis are mainly determined during the analysis of echocardiographic images. Tongue images provide plenty of diagnostic information which will be helpful to reveal the disorders or even the pathological changes of internal organs.

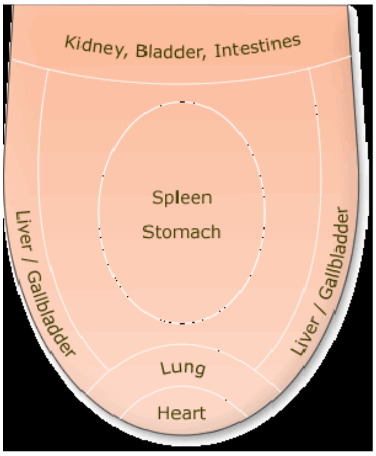

Figure 2 Partitions of the Tongue & its Relation with the Internal Organs

II. PROPOSED METHODOLOGY

a) Echocardiographic Image Dataset and Tongue Image Dataset

A dataset of 300 echocardiographic images were collected from the hospital. Echocardiographic images included both normal and infarct cardiac pathology. The echocardiographic images were manually classified into healthy and unhealthy states with the help of an expert cardiologist. A dataset of about 28 tongue images were obtained which included both healthy and unhealthy cardiac conditions. Figure 3 shows the echocardiographic images of a healthy person and the one with mitral valve regurgitation. Tongue images of persons with healthy and unhealthy cardiac states are depicted in Figure 4.

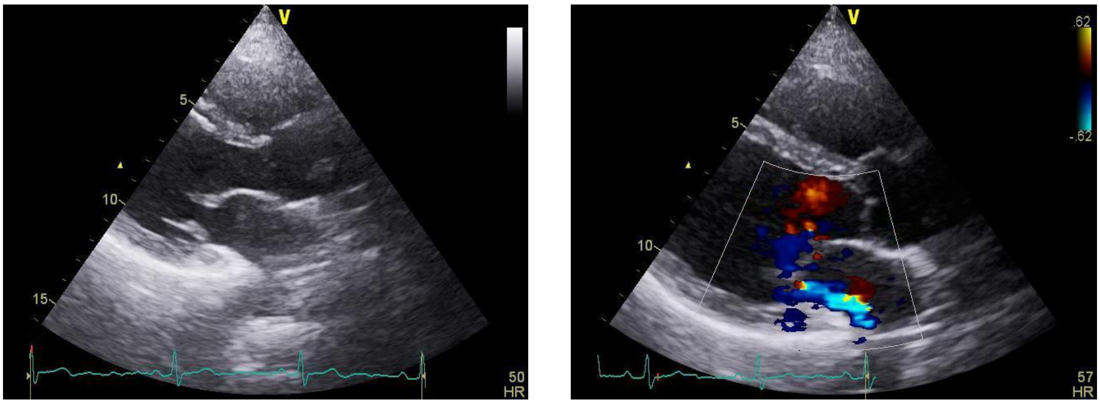

Figure 3: Healthy Echo & Mitral Valve Regurgitation

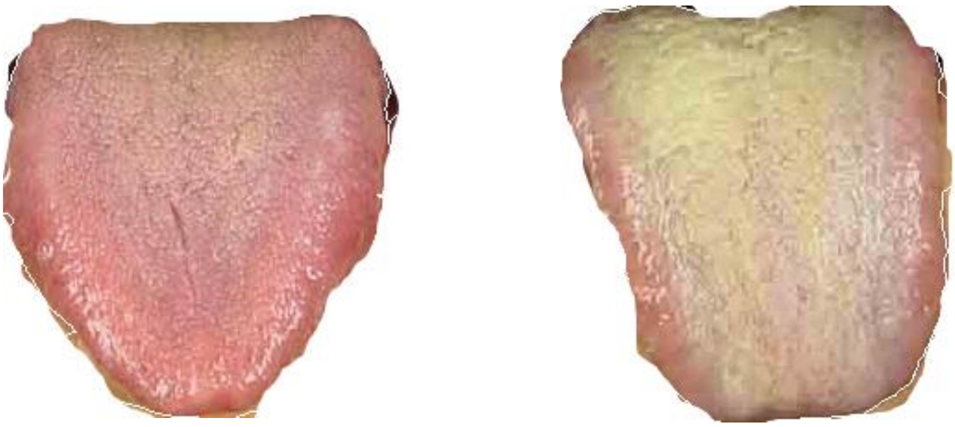

Figure 4 Tongue Images of Healthy and Unhealthy Cardiac Conditions

b) Image Denoising

Removal of the noise is an important step in the cardiac disease diagnosis. This is carried out using the following steps- (i) Fourier transform was performed which is represented by equation (1) (ii) filtering the frequency components using a Gaussian Low pass Filter represented by equation (2) (iii) To reconvert the image back to spatial domain inverse Fourier transform was performed represented by equation (3).

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-i2\pi(\frac{ux}{M}+\frac{vy}{N})} \quad (1)$$

$$H(u,v) = e^{-D^2(u,v)/2D_0^2} \quad (2)$$

$$g(x,y) = 1/MN \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F'(u,v) e^{i2\pi(\frac{ux}{M}+\frac{vy}{N})} \quad (3)$$

where f(x,y) represents the processed image, M and N denote the resolution, F(u,v) is the Fourier transform result, H(u,v) is the filter transfer function, F'(u,v) represents the result of convolution between F and H functions, g(x,y) is the inverse Fourier transform, D(u,v) represents the distance from the point (u,v) to the center of the filter and D_o is the parameter associated with the standard deviation.

c) *Binarisation and Canny Edge Detection*

Otsu's global binarisation method was employed to obtain an optimal threshold. This technique divides the histogram of the image into two classes so that the intraclass variance will be minimal.

Canny detector is used for the edge detection. It is computed using an algorithm comprising of the following steps. It involves smoothing followed by finding the gradients, non maximum suppression and hysteresis. Canny edge detector checks for the intensity discontinuities and a threshold value is chosen depending on which the core boundary is held or discarded.

d) *Feature Extraction*

The classification process is not globally focused on the entire image of the LV. To classify the position of the mitral valve, an ROI with rectangular shape has been identified [1]. The entire image is scanned by using a mobile rectangular mask with height of H pixels and width identical to the image width. The coordinates of the left corner of the sliding mask are (1, h), where $h \in [1, \text{image height} - H + 1]$. The scanning process identifies the regions of interest. ROIs consist of the rectangle

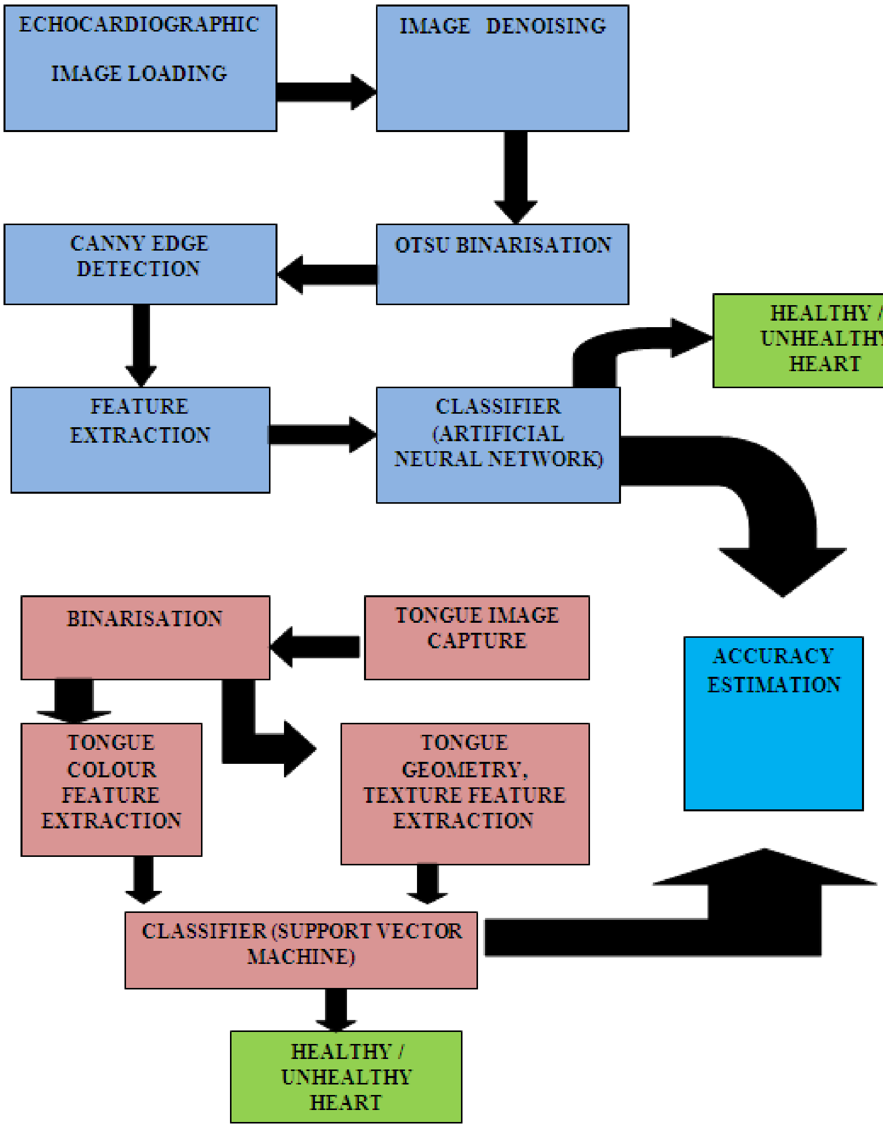

Figure 5 Flowchart of the Algorithm

with the highest number of contour pixels. The proposed image feature vector has two elements $p = [p_1, p_2]^T$. p_1 is the maximum number of contour pixels used for computation and p_2 represents the biggest horizontal length of the individual contours which are present inside the rectangular interest area. p_2 is used to eliminate the small false regions. In addition to the sliding mask technique, feature extraction was also done by using Gray level Co-occurrence Matrix (GLCM). These features extracted were applied to the classifier. GLCM is one of the most widely used statistical tools for extracting texture information from images.

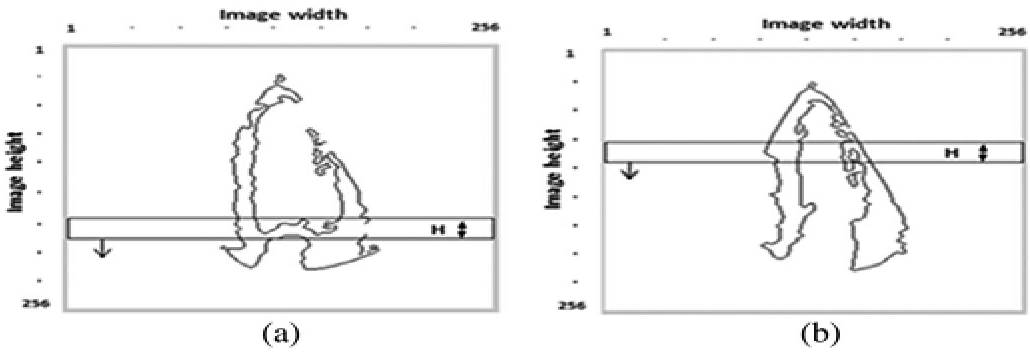

Figure 6 Feature Extraction using Sliding Mask

e) Classifier

The artificial neuron is inspired from real biological neuron. Neuron outputs +1 when the net input reaches a threshold. By the supervised training of artificial neural network it can predict the output accurately. Once the artificial neuron is trained, the classification becomes fast. Artificial neural network is used as the classifier for the diagnosis of cardiac disorders in echocardiographic images whereas support vector machine is employed as the classifier to identify the unhealthy tongue images from the healthy ones.

f) Tongue Color Feature Extraction

After capturing the tongue image, segmentation is done to separate foreground pixels from background pixels. Tongue colour gamut [4] represents all possible colours that appear on the tongue surface within the red boundary which is depicted in Figure 7. The tongue colour gamut was established by plotting the foreground pixels onto the 1931 chromaticity diagram. It is revealed that 98% of the tongue pixels lie inside the black boundary. A total of 12 colours were selected with the help of RGB colour space. Colours include C (Cyan), R (Red), B (Blue), P (purple), DR(Dark Red), LR (Light Red), LP (Light Purple), LB(Light Blue), BK (Black), GY (Gray), W (White) and Y (Yellow).

The basic principle behind feature vector extraction is to compare every pixel's colour intensity with the 12 colour centres and assign the nearest colour [4]. All foreground tongue pixels in sRGB color space are converted to CIEXYZ colour space according to the following equation

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.4124 & 0.3576 & 0.1805 \\ 0.2126 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9505 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (4)$$

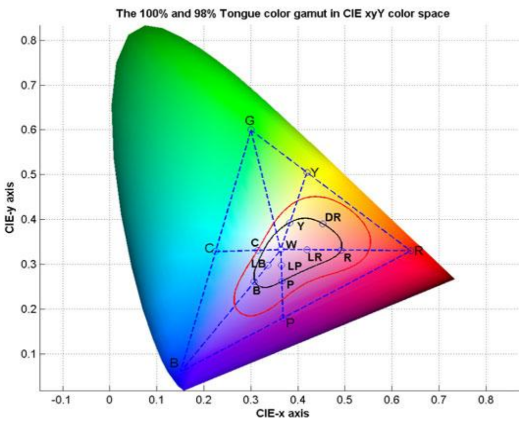

Figure 7 Tongue Colour Gamut Representations

CIEXYZ is converted to CIELAB using

$$L^* = 166.f(Y/Y_0)-16$$

$$a^* = 500.[f(X/X_0)-f(Y/Y_0)] \quad (5)$$

$$b^* = 200.[f(Y/Y_0)-f(Z/Z_0)]$$

where X_0,Y_0,Z_0 are the CIEXYZ tristimulus values of the reference white point. After finding all foreground pixels, the total of each colour is summed and divided by the total number of pixels. This forms the colour feature vector where v= [c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11}, c_{12}].

g) Tongue Texture and Geometry Features

Texture feature is extracted at the tip of the tongue; mainly because the tongue tip is related to the heart. Gabor filter is commonly used in image processing for the texture representation. A 2-D Gabor filter is defined by

$$G_k(x,y) = \exp(x'^2 + \gamma^2.y'^2/-2\sigma^2)\ \cos(2\pi x'/\lambda) \quad (6)$$

where $x' = x.\cos\theta + y.\sin\theta$, $y' = -x.\sin\theta + y.\cos\theta$, σ is the varience, λ is the wavelength, γ is the aspect ratio of the sinusoidal function. A total of three σ and four θ are selected, thereby extracting 12 features.

Thirteen geometrical features are extracted which are used to define and classify 5 tongue shapes based on TCM, rectangle, acute and obtuse triangles, square and circle. A decision tree [7] was used to classify a tongue into one of the five shapes. The width, length, length-width ratio, smaller half distance, center distance, center distance ratio, area, circle area, circle area ratio, square area, square area ratio, triangle area, triangle area ratio were computed. The features can be obtained as shown below and illustrations are depicted in Figures 8 & 9.

1. Width $w=x_{max}-x_{min}$
2. Length $l=y_{max}- y_{min}$
3. Length-Width Ratio lw=l/w
4. Smaller Half Distance z= min (l,w)/2
5. Center Distance $cd= (\max(y_{xmax}) +\max(y_{xmin}))/2-y_{cp}$ where $y_{cp}=(y_{max} +y_{min})/2$
6. Center Distance Ratio cdr=cd/l
7. Area, a= Number of tongue foreground pixels
8. Circle Area $ca=\pi r^2$
9. Circle Ratio Area car=ca/a
10. Square Area $sa=4z^2$
11. Square Area Ratio sar =sa/a
12. Triangle Area, ta= Area of triangle defined within tongue foreground pixel
13. Triangle Area Ratio tar=ta/a

Decision tree is used to classify tongue shapes. After obtaining the tongue geometrical features, average radius is fist calculated as $r_{avg}=(l+w)/4$. After that Tsc is computed as: $T_{sc}=a/r_{avg}^2$ followed by $T_{rao}=a/(l.w)$*. It has been investigated that a person with Chronic Heart Disorders (CHD) will have the tongue shapes mostly classified into either acute or obtuse triangle [7]. Decision tree is shown in Figure 10.

III. Results And Discussion

The experimental echocardiographic images were divided into two sets by an expert cardiologist. The expert manually labeled the images into healthy and unhealthy. The experimental images came from a blend of healthy and cardiac patients that suffer from myocardial infarction. After denoising, higher values of Signal to Noise Ratio (SNR) and Peak Signal to Noise Ratio (PSNR) are obtained and lower values of Mean Absolute Error (MAE) and Mean squared Error (MSE) are obtained. This indicates a better denoising scenario. The output obtained in the first part of the project is depicted in Figure 11. The loaded echocardiographic images were classified into healthy and unhealthy ones by an artificial neural network and an accuracy of around 90% was obtained.

Colour feature extracted for an unhealthy (CHD) tongue sample is depicted in Figure 13. It is observed that for a healthy sample the majority of pixels are Cyan and for the Chronic Heart Disease (CHD) the majority of the pixels are Purple. Geometry features of the tongue also play a major role in the effective diagnosis of heart disease. Thirteen geometrical features are extracted which are used for classify a tongue into five shapes. For the selected sample lw=1.0661, T_{rao}=0.7905 and t_{rect}= 0.85; Since lw≥t_{ao} and Trao<t_{rect}, the shape is an acute triangle which means it is an unhealthy tongue sample. An accuracy of around 87% is obtained in this case.

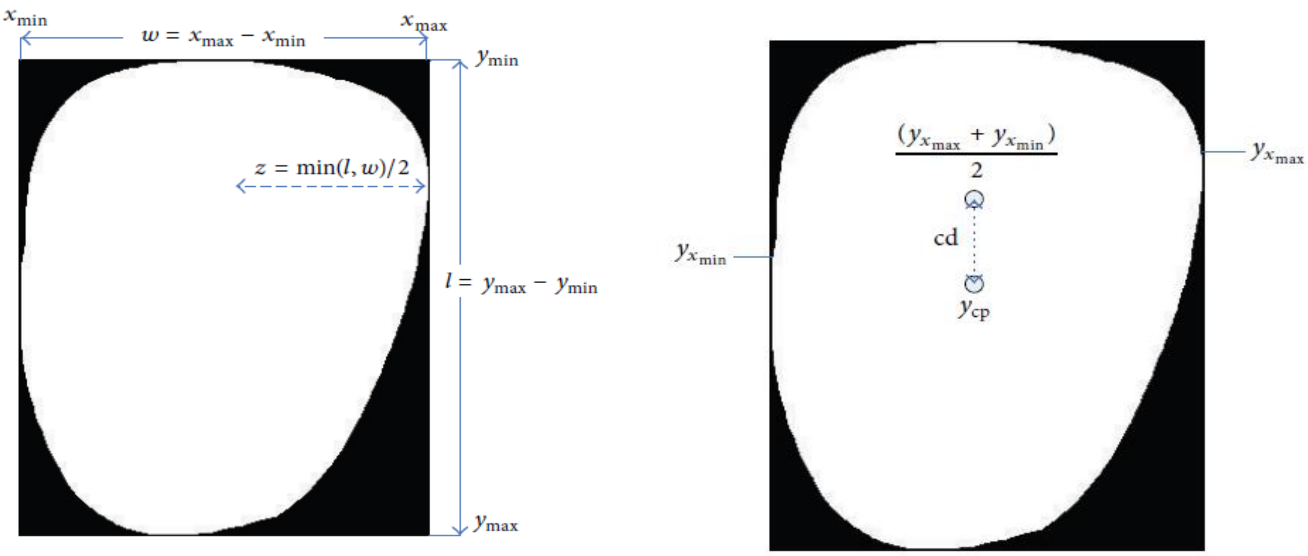

Figure 8 Illustration of Feaures1,2,4,5

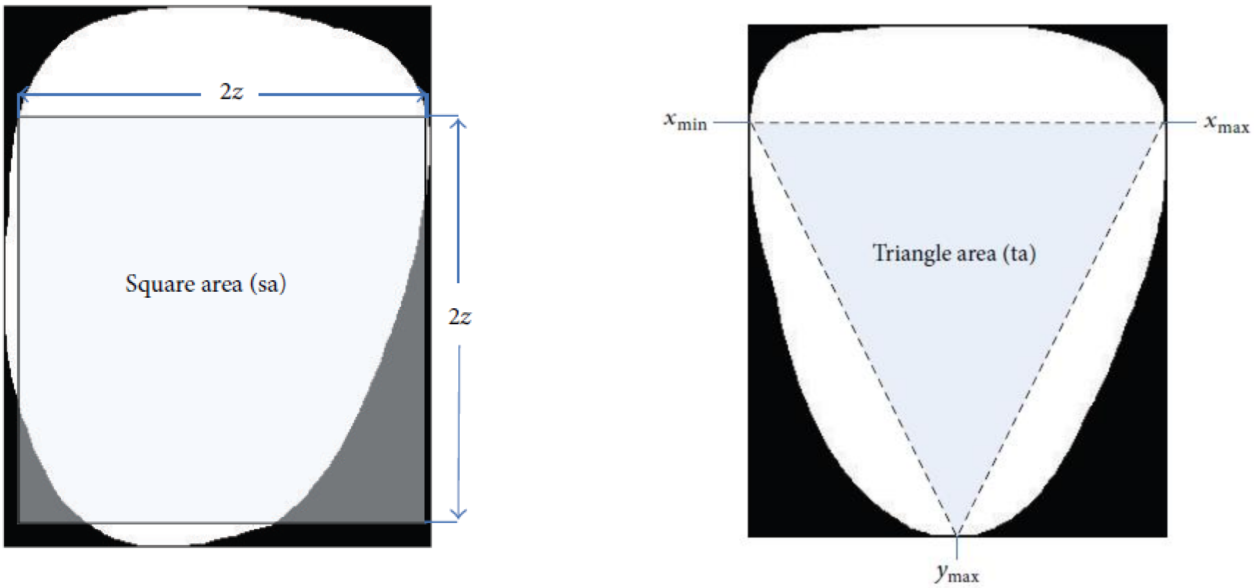

Figure 9 Illustration of Features 10,12

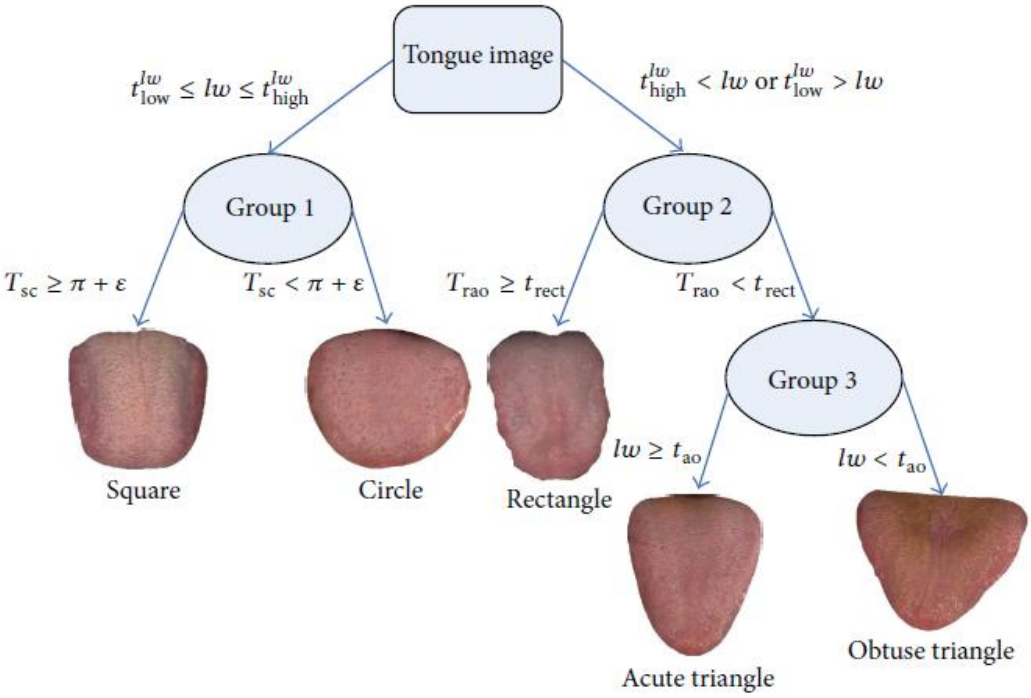

Figure 10 Decision Tree to Classify Tongue Shapes

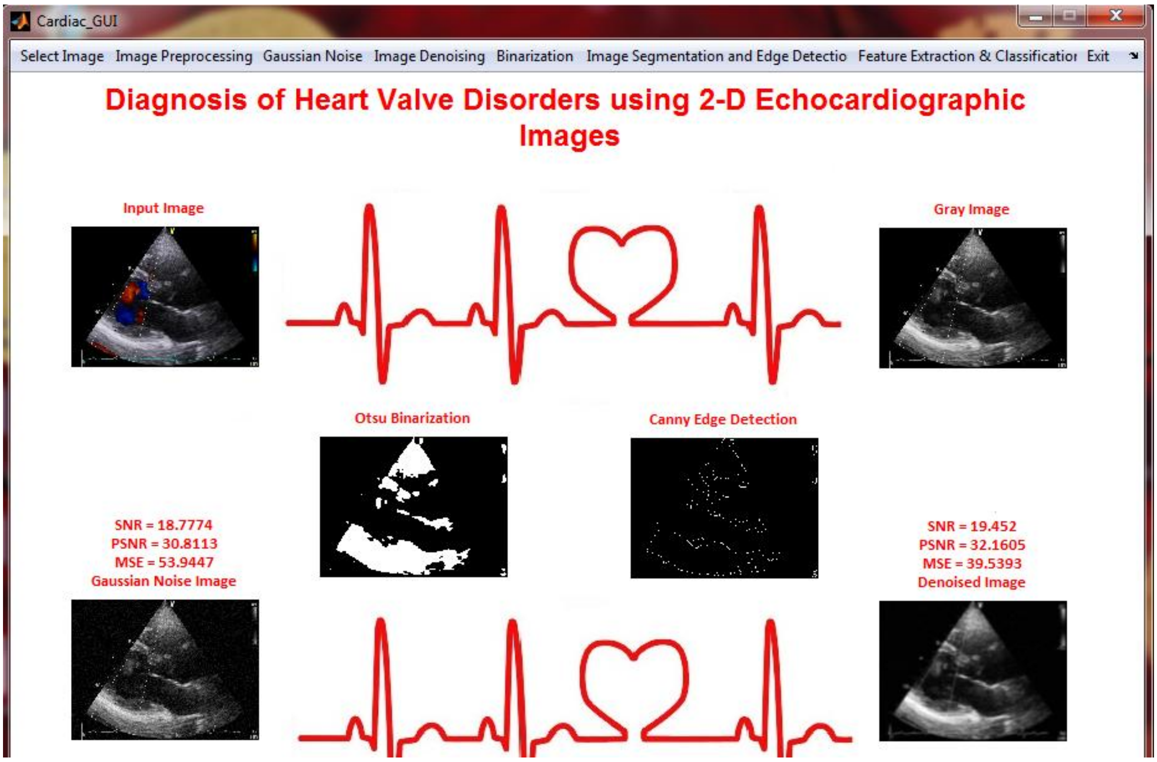

Figure 11 Diagnosis of Cardiac Disorders using Echocardiographic Images

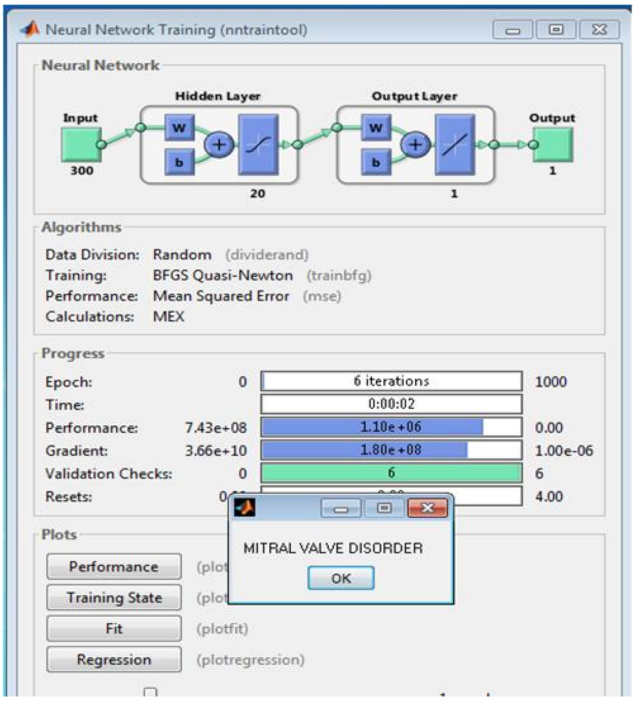

Figure 12 Classifications by Artificial Neural Network

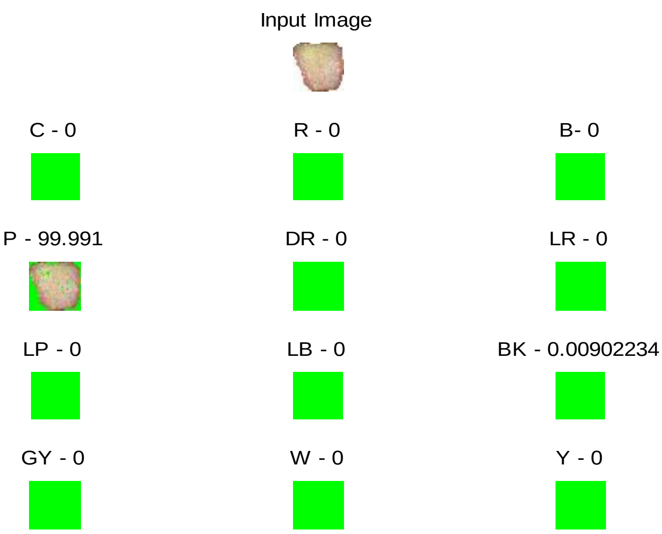

Figure 13 Colour Feature Extraction of an Unhealthy (CHD) Sample

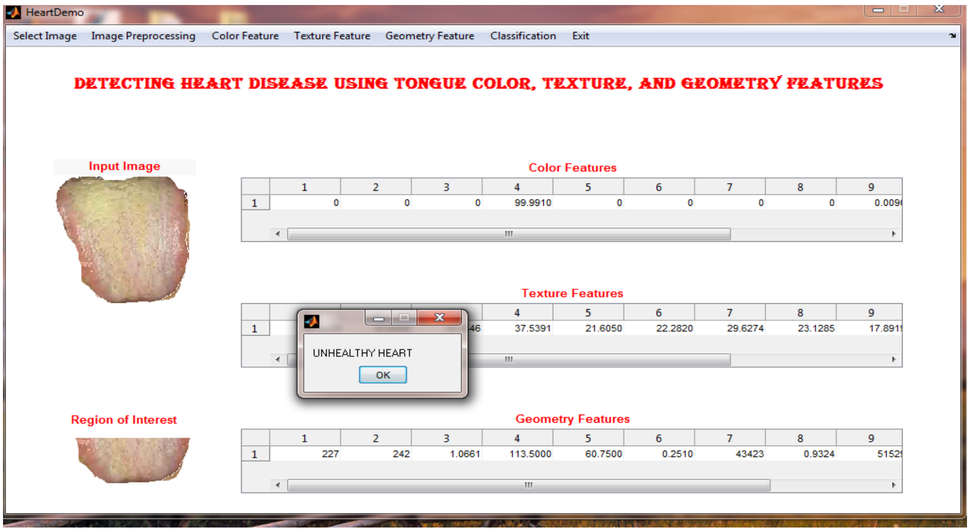

Figure 14 Diagnosis of Chronic Heart Disease using Tongue Features

IV. Conclusion

This project proposed a method for diagnosing the cardiac disorders using 2-D echocardiographic images and tongue features. Accuracy estimation is done in both the cases. An automatic tongue diagnosis system can be developed as an application in smart phones. It would be great if a system could be developed which could identify cardiac disorders by using the echocardiographic and tongue image datasets of the same person.

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Author(s) Profile

Ms. Anu Reeby John, pursuing Masters Degree in Communication Engineering at Amal Jyothi College of Engineering, Kottayam, Kerala, India. She has obtained her Bachelor Degree from Mahatma Gandhi University, Kerala, India.

Mr. Jose J Edathala, works as Assistant Professor at Amal Jyothi College of Engineering, Kottayam, Kerala, India. He has publications in both National and International Journals. His areas of interest include Sensor Systems and Biomedical Image Processing.