

CHAPTER-VI

DECISION SUPPORT SYSTEM FOR CONGENITAL HEART SEPTUM DEFECT DIAGNOSIS BASED ON ECHOCARDIOGRAPHY FEATURES USING NEURAL NETWORKS

6.1 Introduction

One of the clinical tests performed to diagnose Congenital Heart Septum Defect is the Echocardiography. Through this test a physician confirms either the defect is present or not by viewing the septum of the heart. In addition to this, a physician also extracts the features like the location of a defect, size of the defect, number of defects present, etc., in case of presence of a defect. But manual extraction of features is a difficult task for a physician because the features are not extracted by the physician instead they are extracted a trained sonographer, where there is chance of passing inaccurate data to the physician.

Therefore, in the present study, an algorithm is developed to automatically analyze and to extract the features from Echocardiography based on Digital Image Processing techniques. Also, a Decision Support System is developed to automatically classify the Congenital Heart Septum Defect Diagnosis based on Echocardiography features using Backpropagation Neural Network model. The Network is trained by using a Delta Learning Rule. The activation function used in this system is the sigmoid function. The proposed

algorithm and Decision Support System are implemented in MATLAB 7.3 with GUI features.

6.2 Echocardiography

Echocardiography (EK-o-kar-de-OG-ra-fee) or Echo is a painless test that uses sound waves to create pictures of the heart with the use of a transducer (probe) placed on the chest wall. High frequency sound waves inaudible to the human ear are sent from the probe and directed toward the heart. As the sound goes through the different structures of the heart, part of it bounces (echoes) back to the probe and is interpreted by the ultrasound machine into images of blood flow within the beating heart. The test is performed by a sonographer trained in cardiac ultrasound and is interpreted by a cardiologist. The test is useful for assessing the size of the heart chambers and walls, heart muscle function, heart valve function, blood clots or masses in the heart, fluid around the heart, presence of holes or defect between the heart chambers, and abnormalities of blood flow within the heart. The test can take from 30 to 60 minutes depending on what information the physician requests. An Echocardiography image of a normal heart is shown in fig 6.1 and an abnormal heart of type Atrial Septal Defect is shown in fig 6.2.

Fig 6.1 shows the four heart chambers of the Echocardiography namely left atria, right atria, left ventricle and right ventricle and the valves namely Mitral Valve and Tricuspid Valve.

The *left ventricle (LV)* is the main workhorse of the heart, pumping the oxygen-rich blood to the entire body through the aorta. The muscular walls of the heart are called the myocardium, normally about 1 cm in thickness in the left ventricle. The blood filled cavity is roughly shaped like a cone and accommodates approximately 100 ml at the end of diastole (the filling portion of the cardiac cycle). The tasks for echocardiography in the evaluation of the left ventricle are to measure the size of the chamber and the thickness of the walls and ensuring that all of the walls of the ventricle are contracting in a uniform and synchronous manner.

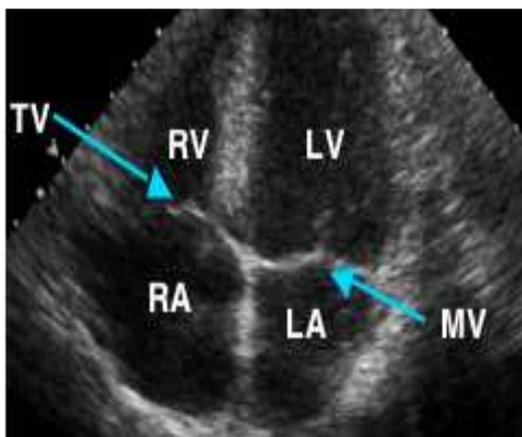


Fig 6.1: Echocardiogram image of a normal heart

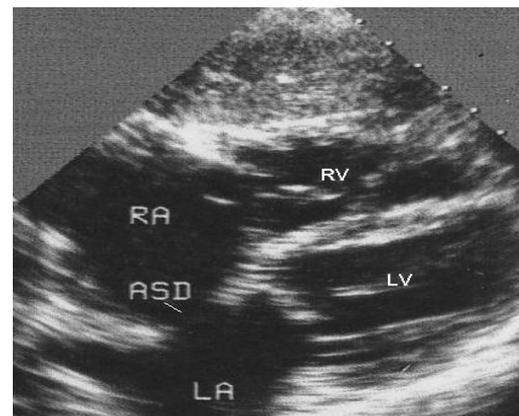


Fig 6.2: Echocardiogram image of an abnormal heart

The *right ventricle (RV)* is the other pumping chamber, which pumps oxygen-poor blood through the pulmonary artery to the lungs, where oxygen is replenished. The right ventricle normally pumps at lower pressures and the walls are thinner, which are less than 0.5 cm. Its shape is more like a crescent

and it is located in front of the left ventricle directly under the sternum. The echocardiography evaluates the shape, size, and wall thickness of the right ventricle.

The *left atrium (LA)* is the reservoir for the oxygen-rich blood returning from the lungs through the pulmonary veins. It holds about 50 ml and partially empties into the left ventricle during diastole. The major task of the echocardiogram is to measure the size of the left atrium.

The *right atrium (RA)* is the reservoir for the oxygen-poor blood returning from the body through the major venous channels, called the inferior and superior vena cava. It holds about 50 ml and partially empties into the right ventricle during diastole. Most of these tasks can be accomplished with transthoracic echocardiogram.

The *mitral valve* is comprised of 2 leaflets and it separates the left atrium and left ventricle. When fully open in diastole, the area of the opening is 4 - 6 cm². During systole, the valve is closed but small amounts of back leak known as “mitral regurgitation,” can be detected in more than 25% of totally normal patients. The *tricuspid valve* is comprised of 3 leaflets and it separates the right atrium and right ventricle. When fully open in diastole, the area of the opening is 4 - 6 cm². During systole, the valve is closed but small amounts of back leak known as “tricuspid regurgitation,” can be detected in more than 50% of totally normal patients.

6.3 Automatic Extraction of Echocardiography features using Digital Image Processing Techniques

6.3.1 Introduction

To diagnose Congenital Heart Septum Defect based on Echocardiography, a sonographer trained by a physician, analyzes the Echocardiography image of a patient and extracts the features like determining whether the septum (heart walls) has defect or not, if so the additional features like location of the defect, type of the defect, number of defects present and the diameter of the defects, and passes these data to the physician. Based these data only, a physician confirms whether a defect is present or not. But, manually extracting features from echocardiography and taking a decision is a difficult task for physicians. This is because, all the sonographers are not equally skilled, where there may be chance to send the inaccurate data to the physician and there is a chance for taking a wrong decision by the physician. i.e a poorly trained sonographer may not pass accurate data to the physician, where the decision taken depends on the passed data. Therefore, in the present study, an algorithm is developed based on Digital Image Processing techniques to extract the Echocardiography features automatically.

6.3.2 Material and Methods

Dataset used

The data used for the present study are transthoracic echocardiography images of a patient. To process the Echocardiography images, these are stored in JPG format.

Method

Since the obtained Echocardiography image may contain noise, this must be preprocessed in order to remove the noise from the image. In the developed algorithm, a median filter with a mask size of 11X11 is applied to the obtained Echocardiography image to remove noise from the image and then the preprocessed image is used to extract the features.

6.3.3 Automatic Extraction of Echocardiography features

6.3.3.1 Preprocessing

The images are prone to variety types of noise. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene. Noisy images makes difficult to clinically diagnosis. Therefore, the first step that occurs in the developed algorithm is preprocessing, which is a process of removing noise from the obtained Echo images. Using Digital Image Processing techniques, noise reduction can be accomplished by blurring with a linear filter and also by non-linear filtering. Blurring is used in preprocessing steps such as removal of small details from an image prior to large object extraction, and bridging of small gaps in lines or curves. In the present study, a non liner filter called *Order-Statistics Filter* is used for removing noise. The image after de-noising is shown in fig 6.4. Once the image is de-noised, then the next step that occurs in the

developed algorithm is the extraction of the required features from the de-noised Echo image.

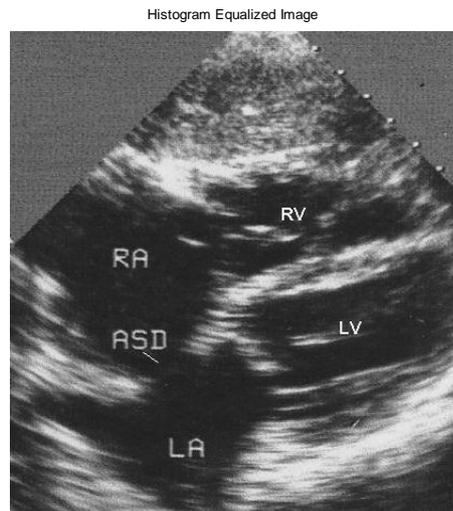


Fig 6.3: The Echocardiogram image after preprocessing

6.3.3.2 Extraction of Echocardiography Features

In order to extract the required features from the processed image, the developed algorithm initially extracts the contour of the heart chambers by detecting the borders of the image.

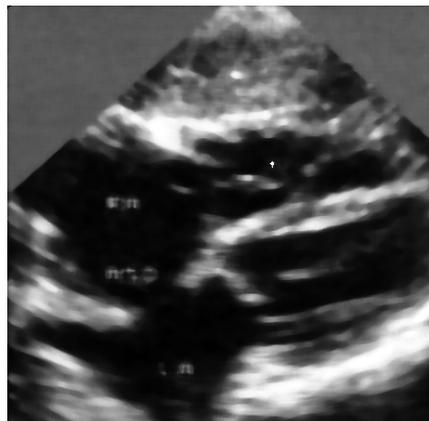


Fig 6.4: The processed image used for feature extraction

Then a midpoint is determined in the processed image. Based on this midpoint the left and the right septum are identified. Once the septum are

identified then it can be used to determine the location, size of the defect, the diameter of the defect and the number of present.

6.4 Decision Support System for Congenital Heart Septum Defect Diagnosis based on Echocardiography features

6.4.1 Introduction

Though the features are extracted automatically from Echocardiography by the developed algorithm, still it is difficult for a physician to diagnose Congenital Heart Septum Defect. Because the features must be extracted by the trained sonographer only, where there is a chance to obtain the inaccurate data by a poorly trained sonographer. This may cause the inaccuracy of the diagnosis and may increase the time delay of the diagnosis. Therefore, in order to improve the diagnosis accuracy and to reduce the diagnosis time, it has become a demanding issue to develop an efficient and reliable medical Decision Support System [KAAE04] to support yet and still increasingly complicated diagnosis decision process. Since, the soft computing methods such as Neural Networks [Luc96] have shown great potential to be applied in the development of medical Decision Support System for diagnosis of Heart Diseases, in the present study also, a Decision Support System is developed to perform the Congenital Heart Disease Diagnosis classification based on the Echocardiography features.

6.4.2 Materials and Methods

Parameters used

The parameters that are used to perform Congenital Heart Disease Diagnosis classification based on Echo are age and the features extracted from the Echo by the developed algorithm. In the present study, to train and test the network, a total number of 200 samples are used. Each sample is having a set of 6 input parameters and one output parameter. The parameter names and the allowed values for that are described in table 6.1.

#No	Attribute Name	Description	Allowed Values
1	Age	Patients age	Continuous
2	Has a Defect	Determining whether a patient has a defect or not	Binary
3	Location of a Defect	Represent the location of the defect, where it is present	Binary
4	Type of a Defect	Determines whether the defect is ASD or VSD	Binary
5	Number of Defects	Which represents the number of defects present	Binary
6	Diameter of a Defect	Represents the diameter of the defect in terms of mm	Continuous

Table 6.1: Parameter Names, Description and their Allowed Values of DSS for CHSD Diagnosis based on Echo features

Method

In the present study, in order to develop a Decision Support System for Congenital Heart Septum Defect Diagnosis based on Echocardiography features, initially the Echocardiography features are extracted by applying the developed Echocardiography feature extraction algorithm to the input images. Then, a Backpropagation Neural Network (discussed in section 2.2.7) is built by

taking input parameters of the Congenital Heart Septum Defects data (Echocardiography features along with the basic information). The network is trained using a supervised Delta Learning Rule. The dataset used to train the network is the Congenital Heart Septum Defect database, which are designed based on the extracted Echocardiography features along with the basic information (Age) of a patient. The activation function used in this model is the sigmoid function. Once the network is trained, then it can be used to perform the diagnosis classification automatically for a new pattern. In order to make the Decision Support System user friendly, it is (the front-end) designed using MATLAB's GUI feature. The Decision Support system is developed not only for the diagnosis classification, but it can also be used to store and view the diagnosis result.

The architecture of a Decision Support System for Congenital Heart Septum Defect diagnosis based on Echo features is shown in fig 6.4. From the architecture it shows that, when the Echo image of a patient is given as input by the user, the developed Decision Support System automatically analyzes and extracts features, it does the diagnosis classification automatically and displays the result. The developed Decision Support System also stores the diagnosis result automatically, which can be used to view for future reference.

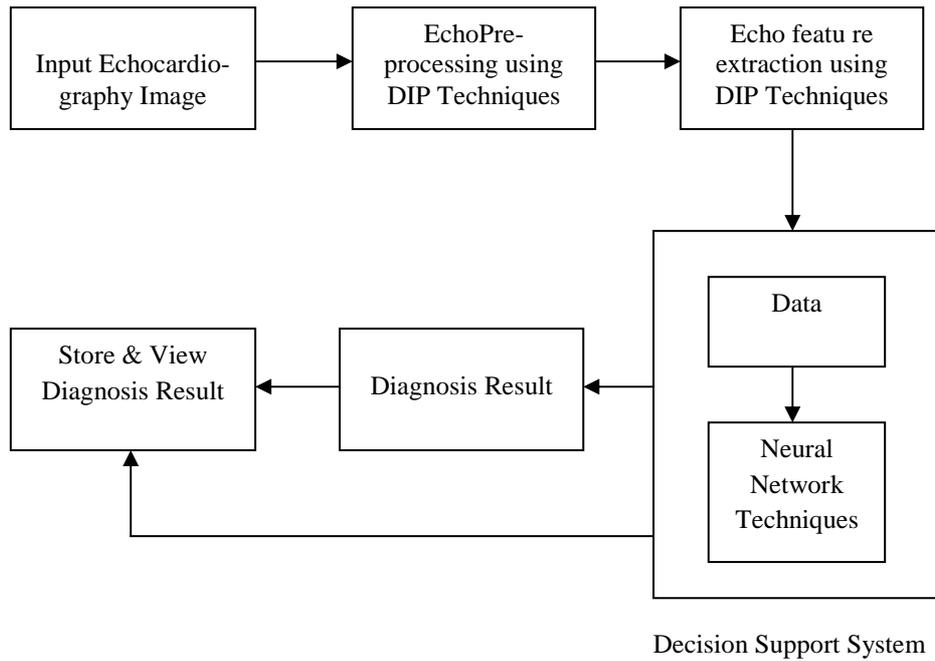


Fig 6.5: Architecture of Decision Support System for Congenital Heart Septum Defect Diagnosis based on Echocardiography

6.4.3 Experiments and Results

Experiment:

The Decision Support System is designed by using MATLAB's GUI feature and is developed by implementing the Backpropagation Neural Network Model. In order to implement Backpropagation Network Model, initially a Feed Forward Neural Network is built with 6 input nodes, 1 hidden nodes and one output node. The input parameters used in this system are the age and the features extracted from the Echo by using the developed algorithm and the output parameter indicates result of the diagnosis in terms of either normal or abnormal. Once the network is built then it can be trained by using a supervised Delta Learning Rule. The activation function used in this model is the sigmoid

function. 200 samples are collected and used to train network. Among these samples 85% of the data are used for training and 15% of the data are used for testing. Once the network is trained then for a new case, the developed Decision Support System does the classification automatically. The least MSE value for the present experiment is 0.0178. Since the Neural Network solutions will not depends on algorithmic solution instead it depends on examples of the previous cases it gives more accurate results than the human diagnosis.

The developed Decision Support System performs five types of operations, which are represented in terms of NEW, ANALYSIS, DECISION, STORE and VIEW pushbuttons. Pushbutton NEW is used to clear the screen (for entering new patient information), the pushbutton ANALYSIS is used to automatically extract the Echo features based on the developed algorithm and to display the results. The pushbutton DECISION is used to perform diagnosis classification automatically based on the selected parameters and to display the result, the pushbutton STORE is used to store the patient information along with the resultant value in terms of text format and the pushbutton VIEW is used to view the stored text file.

The developed Decision Support System can be used by a physician to automatically diagnose Congenital Heart Septum Defects based on Echo features by giving the patient's Echo image as input (in terms of patient number) along with the basic information age of a patient. The developed

system reduces the diagnosis time of a physician and also increases the accuracy of the diagnosis. The developed system is not only used for diagnosis, instead it can also be used to store and view the results of the diagnosis for future reference.

Result:

The developed Decision Support System can be tested by giving the Echo image as input (entering in terms of patient number) along with the basic information of a patient. Once this information is entered, then the ANALYSIS pushbutton can be pressed to automatically analyze and to display the extracted Echo features. Once the features are extracted then the DECISION PUSHBUTTON button can be pressed to automatically display the diagnosis result. The results obtained through the developed system for an abnormal Echo of a patient is shown in fig 6.5.

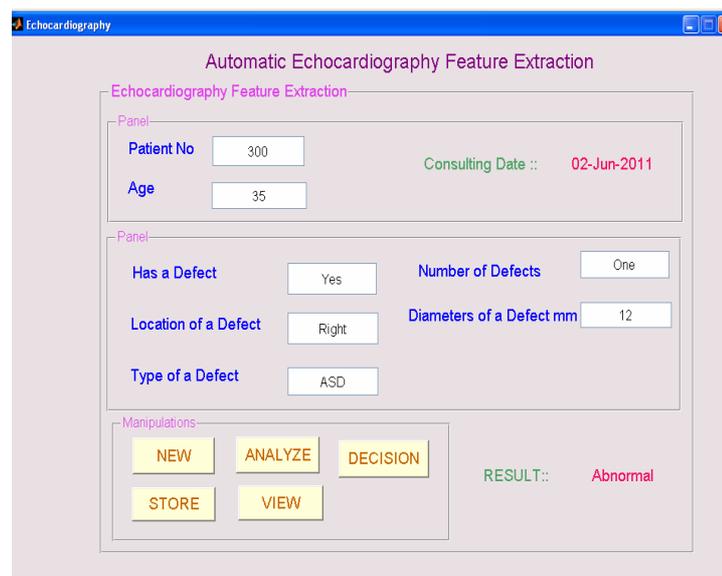


Fig 6.6: Diagnosis result for original Echo image

To store the diagnosis result in a text format, the pushbutton STORE is pressed and to view the stored data text file, the pushbutton VIEW is pressed.

6.5 Conclusion

Congenital Heart Septum Defect Diagnosis based on Echocardiography features is a difficult task for physicians due to the reason that the Echocardiography shows the moving picture of the which is interpreted by the sonographer, where there is chance to get inaccurate data by physician from sonographer. Therefore, the developed Decision Support Systems can be used by a physician to automatically extract Echocardiography features and to perform the Congenital Heart Septum Defect Diagnosis classification automatically based on the extracted features. The developed Decision Support System decreases the diagnosis time and improves the accuracy of the diagnosis.