International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 3, Issue 5, May 2016

Prediction of Congenital Heart Disease in Neonates using Ultrasound Images and Physiological Parameters

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Abstract— **The prenatal detection of fetal cardiac structure is difficult because of its small size and rapid movements but is important for the early and effective diagnosis of congenital cardiac defects.. Congenital heart disease (CHD) is related to defects in the blood vessels which are located inside the heart or the one which are connecting to heart, that are present by birth or sometimes before birth also when the fetus is developing in the uterus. It brings about a narrowing or stenosis of the valves, or a complete closure that obstructs or impedes forward blood stream. Hence the objectives of this project are to extract prenatal features from the ultrasound images and from clinical diagnosis of the neonates(physiological parameters like diabetes hypertension etc). An initial pre-processing is done to remove noise and enhance the images. An effective K means clustering algorithm is applied to the images to segment the region of interest and eliminating empty clusters is performed . Finally an active appearance model is proposed to detect the fetal heart .and a suitable classifier (Naive Bayes) designed for the features according to the statistical characteristics, quantitative or qualitative dataset. Feeding a set of features in the training dataset, use these features to develop the classification algorithm to find CHD .**

Key words—**Congenital heart defects (CHD), Fetal heart, K means clustering, Median filtering, Ultrasound images, Bayesian classifier**

I. INTRODUCTION

Fetal cardiac defects are the most common congenital abnormality found at birth and are the primary reason for the death of the new-born. Fetal heart anomalies are found to affect 1% of all live births . More than one-third of all malformations found after delivery are congenital heart defects (CHD). Only 4-7% of malformations detected before delivery are cardiovascular defects. Despite the widespread use of ultrasound during pregnancy, the vast majority (80- 90%) of fetal heart abnormalities are thus not suspected prior to the birth of the baby. Prenatal diagnosis of CHD can be difficult, but is valuable because outcome for certain abnormalities can be dramatically improved by accurate diagnosis and a adequate preparation.

International and national prospective studies of prenatal screening for heart defects show that, up to now, only 10%-30% of all cardiac defects or 20%- 50% of discoverable cardiac lesions are actually diagnosed prenatally . 50% of all infant deaths can be attributed to congenital heart disease or cardiovascular malformations. About half of these cardiovascular malformations are severe and usually require one or more surgical procedures in the neonatal period or during childhood. In only about 10%-30% of fetuses with cardiac lesions, there are case-history related or (molecular) genetic risks (family history, teratogens in early pregnancy, Maternal disease, etc). Since a risk factor can currently not be elicited either from the history or with conventional genetic or molecular genetics methods in 70%-90% of congenital heart defects, son graphic "abnormalities" on obstetric ultrasound Screening during prenatal care point the way to effective use of the expertise available in pre- and prenatal centers. If a heart defect has already been diagnosed prenatally, the infant with heart disease can usually be born spontaneously in the relevant prenatal or cardiac pediatric center and be treated and cared for without delay in the affiliated departments, thus avoiding a potentially hazardous postnatal transport. In many cases early interventional and/or surgical treatment is important for improving the prognosis of the neonate with heart disease besides using intensive care and medication.

Cardiologists perform ultrasound scan keeping in mind the end goal to analyze the cardiovascular state of the neonates. Different sorts of heart features are acquired by ultrasound scanning, based on the developing stage of the fetus. In the event that the maternal gestation span is under 37 weeks, then it is a pre-term neonate. Thus, if the maternal gestation greater than 37 weeks, then it is a post-term neonate. The heart features are determined to have appreciation to pre-birth and postnatal condition of the neonate. The features that are acquired from the fetus in the maternal womb are known as prenatal features. Though, highlights acquired from the neonates, after the birth are known as postnatal features. Cardiologists extract various pre-birth and postnatal heart features with various different clinical features. Taking into account their clinical ability, diverse elements are examined to anticipate whether the subject is suffering CHD or not. Subsequently, there is a requirement for a classifier tool, whose algorithm can make use of the results of the clinical features as a training dataset. Hence, the classifier can predict the presence of CHD. A novel technique is proposed for the recognition of fetal cardiac structure from ultrasound images. An underlying pre-preparing is done to remove noise and enhance the images utilizing Gaussian filtering. DWT provides sufficient information for both synthesis and analysis reduces computation time and storage more over very easy to implement A compelling K means clustering algorithm is then applied to the segment the region of interest. At last an active appearance model is proposed identify the structure of the heart.

Input Features-Diabetes Blood Pressure Dysmorphic features Cardiac Apex Cardiac malformations Chronic Systemic Diseases Antenatal Echo result Pregnancy Induced Hypertension is caused due to high blood pressure during pregnancy. It is usually found in 7 to 10 percent of all pregnancies. It is found in young women at the time of their first pregnancy. Women usually develop Gestational diabetes during the 24th week of their pregnancy.

The occurrence of this disease is more in women in comparison to men. It is the cardiovascular disorder which leads to heart failure. The variation in the heart rate, blood pressure, temperature etc. may lead to the incident of CSD. Due to this, mother suffering from CSD may lead to positive case of CHD in the neonate .Diagnosis through ultrasound screening is performed on the fetus. It is the case in which the neonates suffer from ostium atrial septal defect , where the supraventricular and ventricular beats that are premature, are diagnosed in antenatal . There will be chromosome imbalance in the maternal body due to past miscarriages. These features are known as dysmprphic features. Fetal ultrasound scan is done for detecting the presence of congenital malformations. It helps in knowing the developing state of the neonate, effects of immaturity, congenital anomalies and, specific transferable or metabolic conditions.

Ultrasound scan is done to see the position of the cardiac apex. It is the lowest exterior part of the heart .The determination of neonates for CHD after extracting prenatal and postnatal parameters is done physically as per the clinical expertise of the Cardiologists. Subsequently, the finding may vary from one doctor to another based on how they analyze by considering the various combination of features and interpreting them. Hence forth, there is no standard methodology embraced so far to foresee CHD from above features. Thus, there is a need for a classification algorithm from these features, which is designed by using various mathematical models. These mathematical models utilize the dataset of previously diagnosed cases by the cardiologists and store the output result of the clinical diagnosis of these cases. The various machine learning algorithms are used based on the type of features (prenatal or postnatal). These algorithms are used to predict the output for a new case.

II. METHODOLOGY

(1) Conversion to Gray Scale:

Before pre-processing the input images are converted into gray scale images to enable the application of filter. The true colour ultrasound image in RGB is converted to gray scale intensity image by eliminating the hue and saturation information while retaining the luminance.

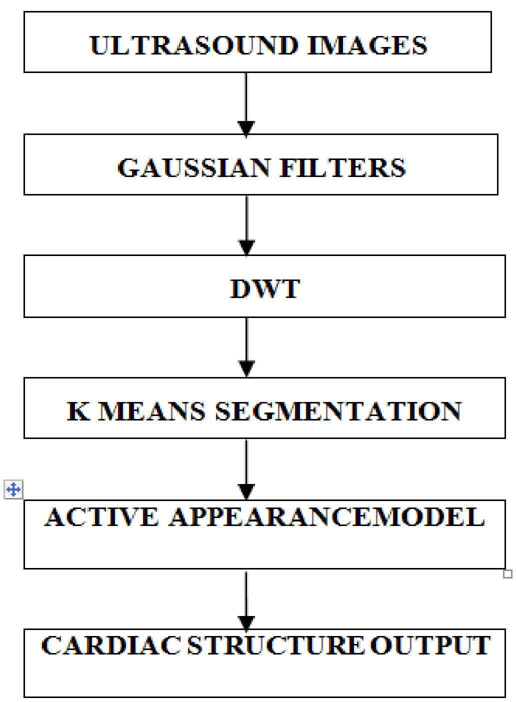

Figure 1. Proposed methodology

(2) Gaussian filtering:

Gaussian filter is a filter whose impulse response is a Gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. Mathematically, a Gaussian filter modifies the input image by convolution with a Gaussian function. The Gaussian smoothing operator is a 2-D convolution operator that is used to `blur' images and remove detail and noise.

(3) DWT

The DWT provides spatial and frequency characteristics of an image. It has an advantage over Fourier transform in terms of temporal resolution where it captures both frequency and location information. The signal is translated into shifted and scale versions of the mother wavelet to generate DWT bands.

The LL sub band gives overall information of the original fetus image, LH sub band represents horizontal information of the fetus image, HL gives vertical characteristics of the fetus image and HH gives diagonal details of the fetus image.

The Haar transformation on one dimension inputs leads to a 2-element vector using equation 1 .

$$\big(y(1), y(2)\big) = T\big(x(1), x(2)\big) \textbf{(1)}$$

Where $T = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$ is the Haaroperator

y(1) and y(2) are simply the sum and difference of x(1) and x(2) which produce low pass and high pass filtering respectively, scaled by $1/\sqrt{2}$ to preserve energy.

The Haar operator T is an orthonormal matrix since its rows are orthogonal to each other (their dot products are zero) and have unit lengths, therefore $T^{-1}=T^{T}$. Hence we may recover x from y using equation 1a.

$$\big(x(1), x(2)\big) = T^{T}\big(y(1), y(2)\big) \textbf{(1a)}$$

For 2D image, Let x be 2×2 matrix of an image, the transformation y is obtained by multiplying columns of x by T, and then the rows of the result by multiplying by T^{T} using equation 2.

$$y = T * x * T^{T} \quad \textbf{(2)}$$

The original values are recovered using equation 3

$$x = T^{T} * y * T \textbf{(3)}$$

An Example of DWT,

If $x = \begin{pmatrix} a & b \\ c & d \end{pmatrix}$ is the original matrix, then DWT is given in equation 4.

Then $y = \frac{1}{2}\begin{pmatrix} a+b+c+d & a-b+c-d \\ a+b-c-d & a-b-c+d \end{pmatrix} \textbf{(4)}$

The DWT bands correspond to the following filtering processes:

- **LL**: a+b+c+d : Low pass filtering in horizontal as well as vertical direction.
- **HL**: a−b+c−d : High pass filtering in horizontal direction and Low pass filtering in vertical direction.
- **LH**: a+b−c−d : Low pass filtering in horizontal and High pass filtering in vertical.
- **HH**: a−b−c+d : High pass filtering in both horizontal and vertical direction.

To use this transform to a complete image, the pixels are grouped into 2x2 blocks and transformations are obtained using equation 5 for each block. The 2 level DWT is applied on fingerprint image of size 256x256 to obtain 128x128 coefficients after first level and 64x64 coefficients after second level stage. The 64x64 LL sub-band coefficients are considered as DWT features.

(4)Segmentation

A simple and effective K means clustering was used to segment region of interest in the ultrasound images. Different methods of segmentation were used earlier. But desirable efficiency was not achieved except for the method proposed by Deng et al which involve automatically locating the region of interest (ROI) using hierarchical block matching algorithm (HBM) [9]. In this method the ROI was located based on motion information. This was based on the characteristic that fast movements of the fetal heart will result in large motion 'energy' in the cardiac region compared to other regions. This novel and efficient method is however very much amputation intensive. K-means is one of the simplest unsupervised learning algorithms that solve the well known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. The main idea is to define k centroids, one for each cluster. The K means algorithm is for partitioning (or clustering) N data points into K disjoint subsets Sj containing Nj data points so as to minimize the objective function, the squared error function:

$$J = \sum_{j=1}^{K} \sum_{n \in S_j} \left| x_n - \mu_j \right|^2$$

where x_n is a vector representing the n the data point and μ_j is the geometric centroid of the data points in Sj. For n sample feature vectors x1, x2, ..., xn all from the same class and falling into k compact clusters, k < n, let mi be the mean of the vectors in cluster i. If the clusters are well separated, a minimum-distance classifier can be used to separate them. Thus, x is in cluster i if ‖ x - mi ‖ is the minimum of all the k distances. This suggests the following procedure for finding the k means:

Make initial guesses for the means m1, m2, ..., mk.

Until there are no changes in any mean,

(i)Use the estimated means to classify the samples into clusters

(ii) For i from 1 to k, replace **m**i with the mean of all of the samples for cluster.

(4) Active Appearance model

In the field of medical image processing, there arises a need to fit the shape of an object to a new image. Models for such matching are not necessary if the object is rigid. However when the object is non-rigid such as a heart or human face, active appearance models can be used to match a user defined set of points to images using their texture information as the matching criteria. Active appearance models are widely used for matching and tracking faces and objects in medical image interpretation and computer vision. It is built during training phase of the project. It is implemented in order to estimate a better guess towards what the real shape in the image is, when some initial estimate for the shape of the object in an image is available. A model is created using the error between the current estimate of appearance and target image. This difference drives an optimization process to create a new better fitting shape. In order to build such a model, a set of training images and shapes is used. The training for the detection of fetal heart structure is done by labeling the boundary of the whole heart and the a trio ventricular septa. The statistical characteristics are calculated by aligning these labeled points and the shape model is thus built. Then "shape free patches" are obtained by comparing the labeled points in the training data to the corresponding mean positions. These are analyzed by eigen decomposition. The texture model is built by eigen analysis. Since there is a correlation between shape and texture models, both models can be controlled using only one parameter. Thus we concatenate the shape and texture model parameters into one vector to give the combined appearance model.

III. CLASSIFIER BASED ON THE PARAMETERS

(1)Data Acquisition

In this project features of prenatal are obtained from the clinical diagnosis and ultrasound screening of the fetus. The prenatal features are taken from the developing fetus.

(2) Prenatal features

Cardiologists extract various prenatal as mentioned above , cardiac features along with various clinical features. Based on their clinical expertise, different features are analyzed to predict whether the subject is suffering from CHD or not.

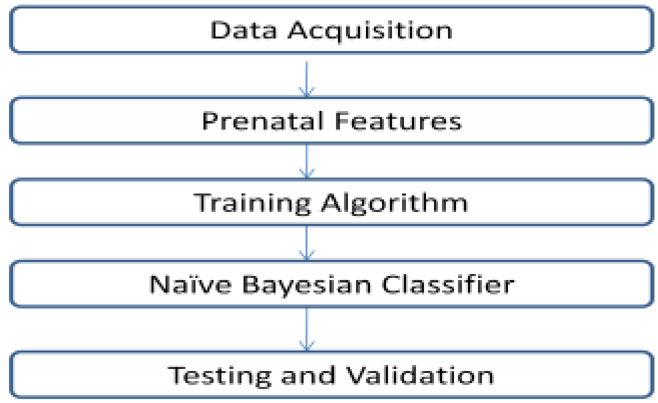

Figure 2. Proposed methodology of classifier

(3) Naive Bayesian Classifier

A supervised learning problem is considered in which an unknown target function is to be approximated f: A→B, or equivalently P (B|A). B is assumed as a random variable having Boolean value, and A as a vector containing n number of Boolean attributes. This can be represented as: A= ‹A1, A2 ...An›, where Ai is the Boolean random variable denoting the *i*th attribute of A. On applying Bayes' rule, P (B=bi | A) can be represented as shown in equation

$$P(B = b_i|A = a_k) = \frac{P(A=a_k|B=b_i)P(B=b_i)}{\sum_j P(A=a_k|B=b_j)P(B=b_j)}$$

Where bm represents the *m*th possible value for B, ak represents the *k*th possible vector value for A, and the summation in the denominator is over all the values of the random variable B.

IV. RESULTS

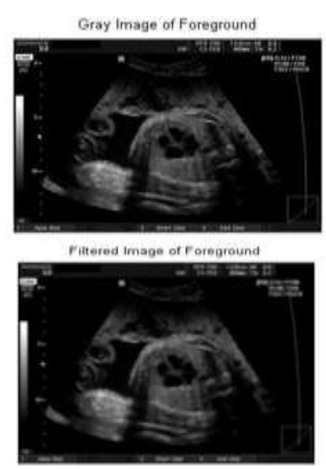

Figure 3. Original and filtered images

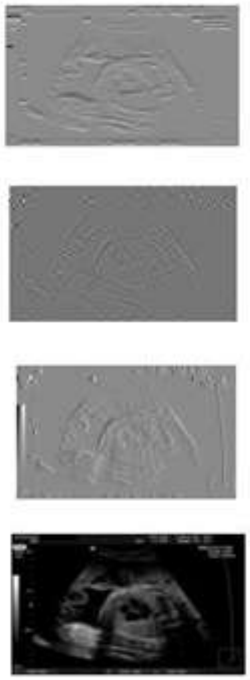

Figure 4. DWT (HH,HL,LH,LL,Respectively)

Figure 5. Region of interest detection

Classifier out put

Input

Antenatal Details(0.None/1.pih/2.gestationaldiabetes/3.chronicsystemicdisease)2

Dysmorphic Features(1.Yes/2.No)2

Cardiac malformations (1.normalfp/2.abnormalfp)2

Cardiac Apex(1.normalca/2.abnormalca)2

Output

likelihood of yes 0

likelihood of no 2.3123

abnormal

V. CONCLUSION AND FUTURE WORK

A novel and efficient method for automated detection of fetal cardiac structure has been proposed in this paper. After the initial pre-processing, the region of interest has been successfully segmented. The final fetal cardiac structure detection is being implemented by active appearance model.

The prenatal features have categorical values; therefore they are classified using Naive Bayesian classifier. This classifier algorithm can be designed on the platforms like Java, Android etc, so that it provides a better user interface and can be added as an application on the control unit of the ultrasound machine. This provides a good feasibility for the cardiologists for an efficient and standardized interpretation of the diagnosis.

REFERENCE

[1]Reshmi Mariam Reji Jacob1, S.Prabakar and DR.K.Porkumaran3] Fetal Cardiac Structure Detection From Ultrasound SequencesInternational Journal of Instrumentation, Control and Automation (IJICA), ISSN: 2231-1890, Volume-2, Issue-1, 2013

[2] Tarun Gangil1, Ranjan Shetty2 Congenital Heart Disease Prediction by Classification based on the Parameters Obtained from Neonates International Journal of fluids and Heat Transfer

[3]N. Maglaveras, S. Maglavera, I. Lekka, I. Chouvarda, and S. A. Netsmart, “Quality home telemedicine services for chronic cardiac disease patients through the interlife platform, *Computers in Cardiology*, vol. 1, pp. 245–248, 2006.

[4] P. S. Rao, Dr. P Syamsundar Rao “Atrial septal defect a review,” *InTech Publications,* vol.1, Ed. 1, pp-3-18, 2012, ISBN: 9789535105312.

[5] D. Crowley, “Two-dimensional and M-mode echocardiographic evaluation of fetal arrhythmia,” *Clinical Cardiology Publishing*, vol. 10, pp. 1–10, 1985.

[6]] M. Nakao, K. Maeda, R. Haraguchi, K. Kurosaki, K. Kagisaki *et al* “Cardiovascular modeling of congenital heart disease based on neonatal echocardiographic images.,” *IEEE Transactions on Information Technology in Biomedicine*, vol. 16, pp. 70–79, 2012.

[7] M. Qian, Y. Sun, Q. Wu, Y. Ma, and Y. Chen, " Fetal echocardiography in normal fetuses between 11 and 14 gestational age," Chin. J. Med. Imaging Technol., vol 23, pp. 268–271, 2007.

[8] T.C. Aysal, K.E. Barner, "Rayleigh-maximum-likelihood filtering for speckle reduction of ultrasound images," IEEE Trans. Medical Imaging,vol.26, pp. 712–727, 2007.

[9] Y.Deng, Y. Wang, P. Chen. "Automated Detection of Fetal Cardiac Structure from First-trimester Ultrasound Sequences," IEEE International Conference on Biomedical Engineering and Informatics,2010, pp.127-131.

[10] B. C.Patel, Dr. G.R.Sinha, "An Adaptive K-means Clustering Algorithm for Breast Image Segmentation," International Journal of Computer Applications Volume 10, No.4,pp. 35-38, 2010.

[11] T.F. Cootes, G.J Edwards, and C,J. Taylor, "Active Appearance Models," IEEE Trans. Pattern Analysis and Machine Intelligence, vol.23, pp. 681–685, 2001.