VOL. 15, NO. 10, MAY 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

APPLICATION OF MACHINE LEARNING ALGORITHM TO DIAGNOSE PRENATAL VENTRICULAR SEPTAL DEFECTS FROM ULTRASOUND IMAGES

Kavitha. D[1], C. H. Renumadhavi[2] and S. Sridevi[3]
[1]Department of ECE, RV College of Engineering, MVJCE, India
[2]Department of EIE, RV College of Engineering, Bangalore, Karnataka, India
[3]Department of ECE, Veltech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai, Tamil Nadu, India
E-Mail: kavithalawrencekishore@gmail.com

ABSTRACT

Ventricular septal defect is a hole or multiple hole in the inter-ventricular septum. It is considered to be one of the critical congenital heart defect malformations. The junction between the right ventricle and left ventricle is shown to be as H-shaped symbol, which is identified as the sonographic marker for the ventricular septal defect (VSD).The dataset intended for this work roots from ultrasound images which is ideal to use due to its non-invasive nature. Diagnosing the fetal heart during early eight weeks of pregnancy from ultrasound images is a challenging task due to the continuous movement of the fetus, speckle noise added in the image, low signal to noise ratio that leads to poor quality of the ultrasound images. The proposed work encompasses different preprocessing techniques to remove the inherent speckle noise seen in the ultrasound images. The second step involves Principle Component Analysis (PCA) to extract the features of the heart. The Support Vector Machine (SVM) is the preeminent classifier in the machine learning which optimally classifies the input data. In combining the robust image processing techniques and machine learning algorithm, the simulation results highlights the sonographic marker for VSD screening from 2D ultrasound images. The application of machine learning algorithm proves the eminence outcomes in terms of images than the existing techniques.

Keywords: noise suppression, filter methods, principle component analysis, support vector machine.

INTRODUCTION

Congenital heart disease (CHD) or Congenital heart anomaly is the most common heart disorder present at birth. In India nearly 30% of heart disease is due to congenital anomaly. CHD arises due to genetic predisposition (or) by environmental conditions. In order to decrease the abnormality rate, CHD has to diagnosis prenatally.

- Ventricular septal defect can be split into structural and functional defect. The generic classification system's are [1] Obstruction Defect, [2] Septal Defect [3] Cyanotic Defect,[4] Hypoplasia. Approximately 30 percentile to 55 percentile of these diseases are critical and it needs early intervention in the first year of neonatal life. Hence more emphasis is given in performing through CHD screening for every trimester of pregnant ladies. In spite of enhanced tools available in India, such as 2 dimensional ultrasonography, Echocardiography and color Doppler for prenatal diagnosis of CHD, the cardiological Society of India (CSI) reported that 10% of CHD still exist.

- The Ventricular Septal Defect is one of the critical type of CHD, that reports 20 to 33% among all CHD. The congenital heart defect screening using ultrasound requires high-class exposure in finding the fetal heart chambers and blood vessels. Due to speckle noise inherent in the image, low signal to noise ratio of the US device and continuous movement of the fetus , using US is a challenging task to provide clear ultrasound images. So far none of the research papers discuss about the screening of VSD using 2D ultrasound images. Hence, at this juncture it is prominent to use modern algorithms (SVM) to delineate the structure of ventricular septal defect.

- The types of VSD and sizes of VSD are, small < 4mm,moderate is considered between the range 4-6mm and large VSD should be greater than 6mm.The VSD can be viewed at 16-18 weeks of gestation. The VSD closure depends on the location , size and types of the defect were discussed by shin-yin Hung[2].The different atrioventricular septal defect and their characteristics using ultrasound and the different screening methods such as 2D US, 3D-4D US and Doppler ultrasound were discussed in this paper[1].The highlight of this paper is to reveal the characteristics features of atrioventricular septal defect such as septum premium, abnormal atrioventricular valve and intra ventricular defect. Even though CHD prediction rate is low during early stages, the evaluation of different screening methods using US techniques may improve the diagnostics rate of CAVSD during isolated stage were highlighted by Daniel murugesan.

- A method to identify the sonographic marker of VSD such as H-shaped symbol using preprocessing techniques and supervised Markov random field segmentation approach from 2D ultrasound images were discussed by S. Sridevi. The average segmentation error was compare with the existing methods [3].

- Xing Li[4] proposed the spontaneous closure of isolated VSD, postnatally. For examination, 5855 sample data were utilized. Out of these, 1168 cases, structure abnormalities in cardiac and isolated VSD were enrolled with 335fetus patients. The mean and standard deviation were calculated for all the data. The subjects were divided into 3 groups, group 1 = persistent VSD, group 2 = closed after birth, group 3 = closed during gestation. Assessment among 3 groups were done using analysis of variance (ANOVA).Comparisons between 3 groups were made using chi-square tests. Logistic Regression analysis was made to identify the independent predictor's outcome.

- This paper compares the detection and accuracy rate of different CHD's from a team of maternal fetal medicine specialist and radiologist with those of perinatal cardiologist. VSD was the most frequent anomaly inaccurately diagnosed.The sonographic marker can be identified by means of experienced, trained, careful scanning and skilled operators. The accuracy rate was increased reliably using perinatal cardiologist rather than maternal fetal medicine specialist were proposed by Vincenzo Berghalla [5]

  P.Syama sundar Rao discussed the management of, Supracristal VSD, AV septal VSD, muscular VSD were detailed discussed in this paper[6].
- This proposed work involves the use of support vector machine classifier to classify the normal and abnormal images and to highlight the H- shaped symbol as a sonographic marker for the Ventricular septal defect from the 4 chamber view ultrasound images.

EXPERIMENTAL DATA COLLECTION AND BACKGROUND OF VENTRICULAR SEPTAL DEFECT

The experimental study involves the use of 4-chamber view (4-CV) ultrasound images to screen out the presence of prenatal VSD by employing preprocessing techniques and SVM classifiers. We framed a small dataset that comprises of 112 data to optimally predict the type of prenatal CHD abnormality. The dataset were collected from the nearby hospitals for training and testing.

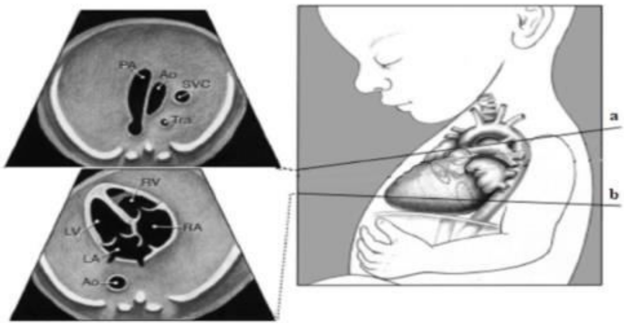


Figure-1. Position of US scanner to visualize 3VVand 4CV imaging planes.

In 3 vessel view (3-VV),three blood vessels such as pulmonary artery, ascending aorta and superior vena cava were seen. Whereas in 4-Chamber view, the right article ,right ventricle , left article and left ventricle were seen Because of low sensitivity or low signal to noise raise outcomes are prone to have more errors.Figure-1 shows the ultrasound scanning using 3VV and 4CV planes.

- The proposed work involves speckle noise reduction using preprocessing techniques ,feature extraction using principle component analysis and classifying the normal and abnormal images using machine learning techniques(SVM).The combined work will help the untrained sonographers to easily screen out the anomaly of the fetal heart.

Background of Ventricular Septal Defect

Ventricular septal defect (VSD) is a type of congenital heart defects present at birth. If the defect is very small, less than 0.5square cm are common. This type of VSD will closes simultaneously on their own. When the defect is greater than 1cm^2, it is associated with larger VSD. This causes increases in the blood pressure of the lungs called "pulmonary hypertension".VSD occurs at the first 8 weeks of fetal life through interaction between interventricular septum permits left to right shunting of blood.

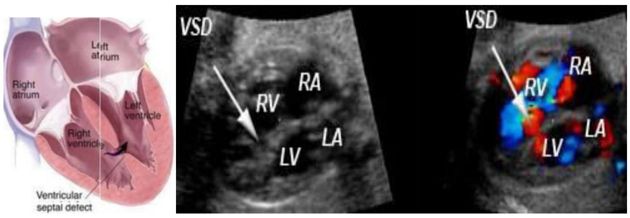


Figure-2. (a) Schematic Diagram of ventricular septal defect, (b) 4-cv Normal fetal heart,(c) Abnormal ventricular septal defect.

- The size of VSD is classified into large, moderate and small. The large size is approximately the size of aortic orifice. The moderate size is still restrictive, but sufficient size to raise right ventricular pressure to ½

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

of left ventricle. The insufficient size to raise right ventricular pressure is the small size.

METHODOLOGY

The methodology adopted in this paper involves segmenting the region of interest(ROI) followed by preprocessing methods like ideal low pass filter, butterworth filer, Gaussian filter, homomorphic filter, mean filter, median filter. These filters were used to evacuate the speckle noise in the US images. The median filter gives efficient results when compared to other filter, by preserving the edges and other high frequency parts of the ultrasound image. The feature extraction method such as principle component analysis is used to extract fetal heart chambers. The support vector machine algorithm is implemented to classify the normal and abnormal images thereby diagnosis the prenatal VSD .

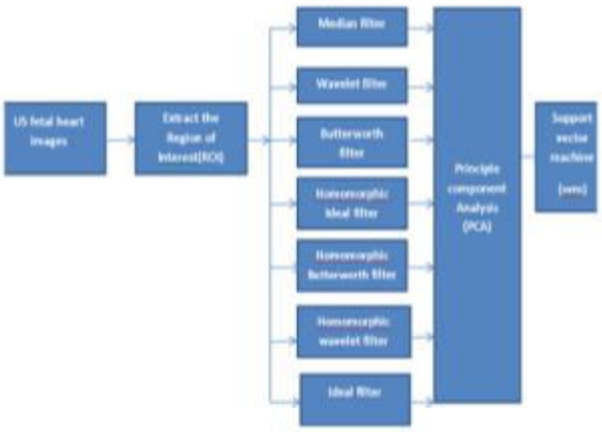


Figure-3. Flowchart involved in the proposed work.

Median Filter

The median filter is a nonlinear digital filtering technique, often used to remove noise from an image or signal. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise (but see discussion below), also having applications in signal processing.

- Image noises random variation of brightness or color information in images and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that obscures the desired information.
- The original meaning of "noise" was "unwanted signal"; signals received caused audible acoustic noise ("static"). By analogy, unwanted electrical fluctuations are also called "noise". Image noise can range from almost imperceptible specks on a digital photograph taken in good light, to optical and radio astronomical images that are almost entirely noise, from which a small amount of information can be derived by sophisticated processing. Such a noise level would be unacceptable in a photograph.

The median filter is an effective method that can, to some extent, distinguish out-of-range isolated noise from legitimate image features such as edges and lines. Specifically, the median filter replaces a pixel by the median, instead of the average, of all pixels in a neighborhood ω,

Y[m,n] = median {x[i,j],(i,j)Є ω}

Where ω represents a neighborhood defined by the user, centered on location (m,n) in the image.

Algorithm for median filter is as follows:

Step 1: Identify the matrix size for the given original image.

Step 2: Identify the matrix size for the corrupted image along with the type of noise added.

Step 3: Create a 3*3 kernel which requires zero padding in all the sides (top, bottom, right and left of the edges)

0	0	0	0	0	0
0	100	245	100	100	0
0	100	245	100	100	0
0	245	100	100	0	0
0	100	100	100	100	0
0	0	0	0	0	0

3*3 kernel matrix for the input datum

Step 4: The first element is processed by moving the kernel with the center valve map with the first element

The sorted data is as follows,
0, 0, 0, 0, 0, 100, 100, 245, 245

Thus the median value = median (0, 0, 0, 0, 0, 100, 100, 245, 245)
= 0

Zero will replace with the first element that is 100.

Step 5: Continue the process until the last element is replaced.

Ideal Filter

The ideal low-pass filter is defined as ―the filter that strictly allows the signals with frequency less than and attenuates the signals with frequency more than the specified cut-off frequency". Ideal low-pass filter is used to reconstruct the signals from discrete samples to their original continuous signal. The transition regions do not exist in ideal low pass filters. A 2D ideal low pass filter is one whose transfer function is given by

$$H(u,v) = \begin{cases} 1, \text{if } D(u,v) \le Do \\ 0, \text{if } D(u,v) > Do \end{cases}$$

Where Do is the specified non-negative quantity and D (u,v) is the distance from point (u,v) to the origin of the frequency plane. An ideal low-pass filter completely eliminates all frequencies above the cut-off frequency while passing those below unchanged: its frequency response is a rectangular function, and is a brick-wall filter. The transition region present in practical filters does not exist in an ideal filter. Ideal filters allow a specified frequency range of interest to pass through while attenuating a specified unwanted frequency range. The following filter classifications are based on the frequency range a filter passes or blocks:

- Low pass filters pass low frequencies and attenuate high frequencies.
- High pass filters pass high frequencies and attenuate low frequencies.
- Band pass filters pass a certain band of frequencies.
- Band stop filters attenuate a certain band of frequencies.
- An ideal filter has very sharp cut-off characteristics, and it passes signals of certain specified band of frequencies exactly and totally rejects signals of frequencies outside this band. Its phase spectrum is linear. Filters are usually classified according to their frequency response characteristics as low pass filter (LPF), high-pass filter (HPF), band-pass filter (BPF) and band-elimination or band stop or band reject filter (BEF, BSF, BRF). An Ideal low-pass filter transmits, without any distortion, all of the signals of frequencies below a certain frequency ωc radians per second. The signals of frequencies above ω radians/second are completely attenuated. ωc is called the cut-off frequency. The corresponding phase function for distortion less transmission is -ωtd. The transfer functionbof an ideal LPF is given by

$$|H(\omega)| = 1, \ |\omega| < \omega c \ 0, \ |\omega| > \omega c$$

The frequency response characteristics of an ideal LPF. It is a gate function. Ideal HPF An ideal high-pass filter transmits, without any distortion, all of the signals of frequencies above a certain frequency ωc radians per second and attenuates completely the signals of frequencies below ωc radians per second, where ωc is called the cut-off frequency. The corresponding phase function for distortion less transmission is -ωtd.

Butterworth Filter

The Butterworth filter is a type of signal processing filter designed to have a frequency response as flat as possible in the pass band. It is also referred to as a maximally flat magnitude filter. Used for Smoothening and sharpening of images. Advantage of this filter is that we can control the sharpening of the filter with the order.

Homomorphic Ideal Filter

Two techniques are combined for best result and this is used for image enhancement and to remove the noise Logarithm of image intensity is taken to remove the noise. High pass filtering is used to support low frequency and amplify high frequencies this filter works

Homomorphic Butterworth Filter

Homomorphic filtering approach performs simultaneous dynamic range compression and contrast enhancement. Homomorphic and Butterworth are combined to improve high frequency techniques. High pass Butterworth is mainly used for image sharpening and to extract the edges for segmentation.

Wavelet Filter

A wavelet is a wave-like oscillation with amplitude that begins at zero, increases, and then decreases back to zero. It can typically be visualized as a "brief oscillation" like one recorded by a seismograph or heart monitor. Generally, wavelets are intentionally crafted to have specific properties that make them useful for signal processing. Using a "reverse, shift, multiply and integrate" technique called convolution, wavelets can be combined with known portions of a damaged signal to extract information from the unknown portions. For example, a wavelet could be created to have a frequency of Middle C and a short duration of roughly a 32nd note. If this wavelet were to be convolved with a signal created from the recording of a song, then the resulting signal would be useful for determining when the Middle C note was being played in the song.

Mathematically, the wavelet will correlate with the signal if the unknown signal contains information of similar frequency. This concept of correlation is at the core of many practical applications of wavelet theory.

As a mathematical tool, wavelets can be used to extract information from many different kinds of data, including - but certainly not limited to - audio signals and images. Sets of wavelets are generally needed to analyze data fully. A set of "complementary" wavelets will decompose data without gaps or overlap so that the decomposition process is mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss.

In formal terms, this representation is a wavelet series representation of a integral function with respect to either a complete, orthonormal set of basic functions, or an over complete set or frame of a vector space, for the Hilbert space of square integral functions.

VOL. 15, NO. 10, MAY 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Homomorphic Wavelet Filter

Wavelets are more general way to represent and analyze multi solution images. Continuous wavelet filter is used with harmonic filter which helps in computing 2D wavelet transform and alter the transformed noising compression and image fusion are all the examples for wavelet filter. This kind of filtering is applied for filtering the MRI scanning and ultrasound scanning images. Wavelets mainly help in representing the features and position of image.

FEATURE EXTRACTION TECHNIQUE

The yield of Pre-preparing is taken as contribution for performing segmentation. Segmentation is an essential advance where it protects the data of the entire image. Segmentation implies part of the first picture into some segments. Here, it is portioned into high contrast pixels in light of thresholding. Thus, these data can be separated by methods for highlight extraction.

- Feature extraction is usually performed utilizing Principle Component Analysis Algorithm. This calculation is generally utilized for design acknowledgment in picture processing. Hence, from the pre-handled picture the highlights of four assemblies of fetal heart are extracted. The highlights are shape, size and width. Principal component analysis is a technique for feature extraction so it combines our input variables in a specific way, then we can drop the - least important‖ variables while still retaining the most valuable parts of all of the variables.

- **Algorithm:**

Step 1: Separate data into Y and X.
Step 2: Take the matrix of independent variables X and, for each column, subtract the mean of that column from each entry.
Step 3: Given the columns of X, are features with higher variance more important than features with lower variance, Take the matrix Z, transpose it, and multiply the transposed matrix by Z.
Step 4: Calculate the eigenvectors and their corresponding eigenvalues of Z^TZ. Take the eigenvalues λ_1 , λ_2 …λp and sort them from largest to smallest. In doing so, sort the eigenvectors in P accordingly..
Step 5: Calculate Z* = ZP*. This new matrix, Z*, is a centred/standardized version of X but now each observation is a combination of the original variable.

The support vector machine classifier was used to classify the different classes of images based on the output of principle component analysis.

RESULTS AND DISCUSSIONS

This section of the paper involved the discussion of processing the fetal heart chambers. The highlight of this proposed work is to identify the H-shaped marker from the ultrasound images. Different filtering techniques are used to suppress the noise from the input image. Second, we used feature extraction method like principle component analysis to extract the features of the fetal heart chambers from the different filtering outputs. Third, support vector machine classifier is used to classify the normal and abnormality present in the ultrasound images

The clinical data sets were collected from the nearby hospitals and web. Nearly 112 Ultrasound images were used for experimentation. Out of 112 US images, 28 images were prone to be abnormal. To validate the outcome of the proposed filter, it was compared with different filters such as, Median filter, Ideal filter, Homomorphic filter, Butterworth filter, wavelet filter. The validation can be proved by means of Mean square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

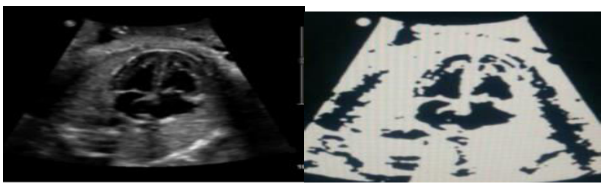
- Mean Square Error (MSE) is used to estimate the amount noise added in the original image in terms of error.

$$MSE = \frac{1}{N}\sum_{i=1}^{n}(Y - Yi)^2$$

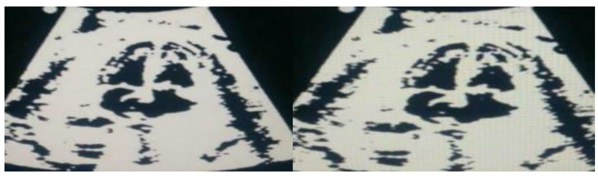
- PSNR is termed as the peak signal to noise ratio which is used to compute the PSNR between two images. The ratio is used as quality measurement between the original and reconstructed image.

$$\text{PSNR} = 10\log_{10}\frac{Max^2}{MSE}$$

Following are the comparison of the processed 2dimensonal ultrasound images



(a) (b)



(c) (d)

Figure-4. Output of the Median filter. (a) Original image,(b) Output of 7*7 image, (c) Output of 5*5 image, (d) Output of 3*3image.

VOL. 15, NO. 10, MAY 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

(a) (b) (c)

Figure-5. Output of the Ideal filter.(a) cutoff frequency of 50Hz, (b) cutoff frequency of 20Hz, (c) cutoff frequency of 40Hz.

(a) (b) (c)

Figure-6. Output of the Butterworth filter.(a) cutoff frequency of 50Hz, (b) cutoff frequency of 30Hz, (c) cutoff frequency of 20Hz.

(a) (b) (c)

Figure-7. Output of the Homomorphic Ideal filter.(a) cutoff frequency of 50Hz, (b) cutoff frequency of 30Hz, (c) cutoff frequency of 20Hz.

(a) (b) (c)

Figure-8. Output of the Homomorphic Butterworth filter.(a) cutoff frequency of 50Hz, (b) cutoff frequency of 30Hz, (c) cutoff frequency of 20Hz.

(a) (b)

Figure-9. Output of the Wavelat and Homomorphic waveletfilter, (a) wavelet cutoff frequency of 50Hz, (b) Homomorphic waveletfilter cutoff frequency of 30Hz.

- The Principle component analysis is used to extract the features of the fetal heart chambers.Thus, the segmented image is shown below.

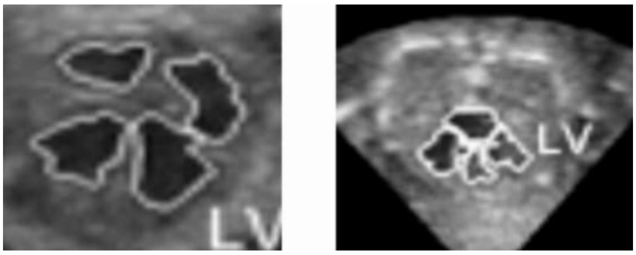
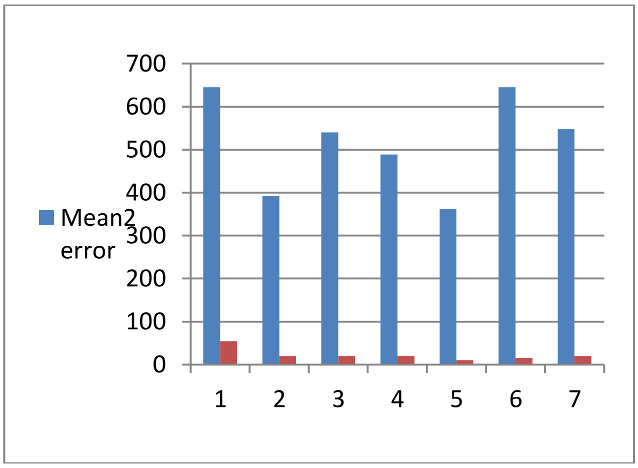


Table-1. Comparison of different filters with respect to Mean Square Error & Peak Signal to Noise Ratio.

Filters	Mean square error	PSNR
Median Filter	645	54.0
Ideal Filter	392	19.94
Butter Filter	540	19.97
Homomorphic Ideal Filter	489	20.009
Homomorphic Butter Filter	362	10.25
wavelet filter	645	15.14
Homomorphic Wavelet Filter	547	20.019



CONCLUSIONS

The proposed work describes the importance of finding the prenatal congenital heart defects (VSD).It is a challenging task in the medical field as the ultrasound image contains enormous amount of noise inherent in it. Before applying these techniques, the 2 dimensional ultrasound images is troublesome to reveal the final conclusion for the radiologist. The proposed work outline the fetal heart chambers thereby predicting the type of CHD, in this paper it is a ventricular septal defect. The table and graph illustrates the efficacy of different filters in terms of peak signal to noise ratio (psnr) and mean square error (mse). The Median filter proves the best results when compare to other filters. This work will help the radiologists to make symptomatic decisions and prior conclusion of fetal heart inconsistencies. The future can be extended to find the other types of congenital heart defects automatically.

REFERENCES

[1] Mureşan D, Mărginean C, Zaharie G, Stamatian F, Rotar IC. 2016. Complete atrioventricular septal defect in the era of prenatal diagnosis. Medical Ultrasonography. 500-507.

[2] Shih-Yin Huang, An-Shine Chao, Chuan-Chi Kao, Chih-Hui Lin, and Ching-Chang Hsieh. Apr-Jun 2017. The Outcome of Prenatally Diagnosed Isolated Fetal Ventricular Septal Defect. Journal of Medical Ultrasound.71-75.

[3] S. Nirmala, S. Sridevi. 2016. Markov random field segmentation based sonographic identification of prenatal ventricular septal defect. 344-350.

[4] Xing Li, Gui-Xian Song, Li-Jie Wu, Yu-Mei Chen,Yi Fan, Yun Wu, Ya-Hui Shen, Li Cao, and Ling-Mei Qian. Dec 2016. Prediction of spontaneous closure of isolated ventricular septal defect in utero and postnatal life. 207.

[5] Greggor R. DeVore, Pei Ni Jone, Gary Satou, Mark Sklansky, Bettina F. Cuneo. May 2019. Aortic Coarctation: A Comprehensive Analysis of Shape, Size and Contractility of the Fetal Heart. Fetal Diagnosis Therapy. p.330.

[6] Youlian Zhu,Cheng Huang. 2012. An Improved Median Filtering Algorithm for Image Noise Reduction. 606-16.

[7] Youlian Zhu, Cheng Huang. Aug-2014. An improved Median filterig algorithm for image noise reduction. 5401.

[8] Hoffman JI. 1995. Incidence of congenital heart disease: I. Postnatal incidence. Pediatr Cardiol. 103-113.

[9] Jin Y, Wang A, Wang Y, Wang Y, Wang W, Hou X. 2012. Natural history of prenatal ventricular septal defects and their association with foetal echocardiographic features. Cardiol Young. 323-326.

[10] Hill GD, Block JR, Tanem JB. 2015. Disparities in the prenatal detection of critical congenital heart disease. Prenat Diagn. 859-63.

[11] Rebekka Lytzen, Niles Vejlstrup, Jesper Bjerre, Olav Bjorn Petersen, Stine Leenskjold, James Keith Dodd, Finn Stener Jorgensen, Lars Sondergaard. May 2019. Mortality and morbidity of major congenital heart disease related to general prenatal screening for malformations. International Journal of Cardiology. 0167-5273.

[12] Greggor R. DeVore, Pei Ni Jone, Gary Satou, Mark Sklansky, Bettina F. Cuneo. May 2019. Aortic Coarctation: A Comprehensive Analysis of Shape, Size and Contractility of the Fetal Heart. Fetal Diagnosis Therapy. p. 330.

[13] YY. F.Li, K.Y. Zhou, J. Fang, C. Wang, Y.M. Hua, D.Z. Mu. August 2016. Efficacy of prenatal diagnosis of major congenital heart disease on perinatal management and periop erative mortality. pp. 298-307.

[14] S Sudheer R. Gorla, Abhishek Chakraborty, Ashish Garg, Rubee A. Gugol, Richard E. Kardon and Sethuramaan Swaminathan. November 2018. Emerging trends in the prenatal diagnosis of complex CHD and its influence on infant mortality in this cohort. Cambridge University Press. pp. 1-7.

[15] GG. OGGE, P. Gaglioti, S. Maccanti, Faggiano, Todros. October 2006. Prenatal screening for congenital heart disease with four-chamber and outflow-tract views: a multicenter study. Ultrasound Obstet Gynecol. pp. 779-784.

[16] D Dhanushree. Y, Indrani. N, Santosh. N, Vidya Vani. R, Dr. Rajeshwari. J. 2018. Heart Disease Prediction By Machine Learning. International Journal Of Engineering Research And Development. 14(6): 01-06, June Ver. I.

[17] Sridevi S. & Nirmala S. 2015. ANFIS based decision support system for prenatal detection of Truncus Arteriosus congenital heart defect. Applied Soft Computing.