Where IMF (j) is the j^{th} mode (or IMF) of the signal, and I_{res} is residual trend. The sifting procedure generates a finite number of IMFs which are nearly orthogonal to each other [5]. These IMFs are processed using kurtosis, instantaneous frequency and Shannon energy criterions. Segments which lies outside Gaussian distribution are correspond to heart sound [3]. S1, S2, systolic and diastolic segments separated from heart sounds.

3.2 Back Propagation Artificial Neural Network (ANN)

Back propagation is systematic method for training multi – layer artificial neural networks [1]. It has mathematical foundation. It multi-layer forward network using extend gradient-descent based delta-learning rule, commonly known as back-propagation algorithm [1]. Back propagation provides a computationally efficient method for changing the weights [1] in feed forward network, with differential activation functions, to learn a training set of input output examples. Network is trained using supervised learning method [1]. The aim of this network is to achieve balance between ability to respond correctly to the input patterns that are used for training and the ability to provide [1] good response to input that are similar [1]. As shown in fig 2 errors at output is measured and it is propagating in back ward direction so it is called back propagation neural network.

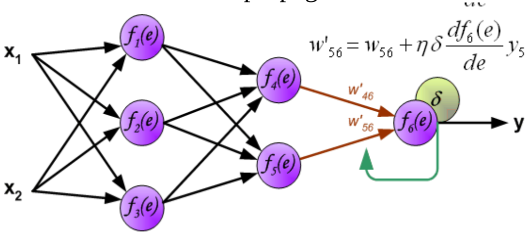

Figure 2: Back propagation algorithm [4]

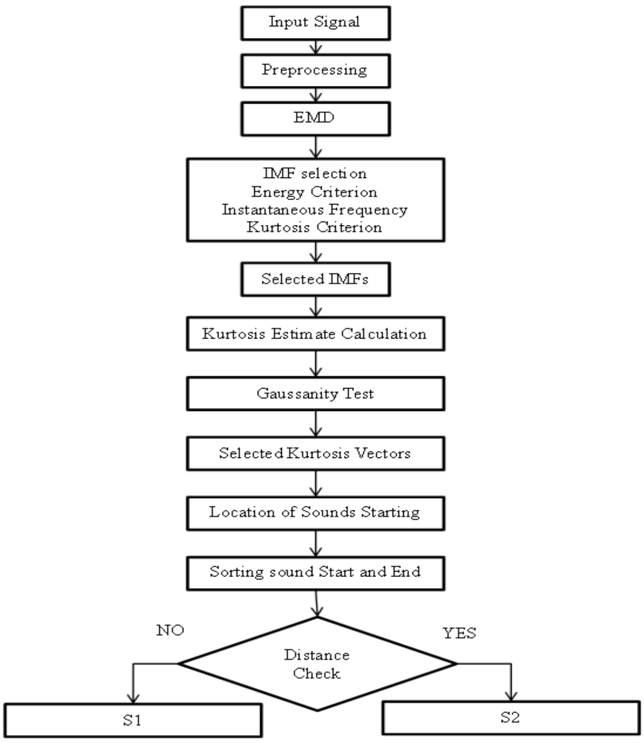

Figure 3: EMD flow to extract heart segments [2]

3. Proposed Approach

3.1 Pre-processing

Input signal x[n] is normalized by making it zero-mean signal and down-sampled to 12 kHz for time efficient computation. This normalized input undergoes 3rd order median filtering to enhance quality of signal followed by 10th order Butterworth filtering with cut off frequency 150Hz [2]. It gives filtered signal $x_f[n]$. Due to filtering with at cut off 150 Hz removes high frequency noise and high frequency murmur that help for detection of S1 and S2 points.

3.2 Empirical Mode Decomposition

Pre-processed heart sound undergoes empirical mode decomposition and gives S1, S2, systolic and diastolic murmurs as an output by following flowchart given in fig 3. Statistical parameters mean, standard deviation, kurtosis and skewness are extracted from segmented components for each sound. These features are used for neural network training and classification.

3.3 Neural Network Classifier

As shown in fig 1 different sound follows different distribution in their time representation. AS, MR, MR and AS mainly depends on systolic and diastolic behaviour. In AS systolic murmur is diamond shaped distribution and diastolic murmur is having fourth sound present. Now is considering third and fourth sound as part of diastolic murmur only. Aortic Stenosis and Mitral Regurgitation are characterised by systolic murmur. Aortic Regurgitation and Mitral Stenosis are characterised by diastolic murmur only. S1sounds low loudness only characterise Mitral Stenosis. S2 sound is normal in all four heart diseases so it is not useful for classification. While developing neural network three back propagation neural network architecture is developed.

1) Systolic and diastolic Neural Network
Systolic murmur is three levels architecture. It is having four inputs, six hidden layers and two output layers. Each layer is having activation function ‘tansigmoid’ and training ‘trainrp’. Tough network classify only two disease output neurons are two because some patients may have both diseases.

2) S1 based Neural Network
S1 neural network is two levels architecture. It is having four inputs and two output layers. Each layer is having activation function ‘logsigmoid’ and ‘tansigmoid’ respectively with training ‘trainlm’.

Output of three neurons gives cumulative decisions. Patients may have two or three different heart valve disease. So output of neural architecture gives eight combinations. Patient with any of combinations is considered.

4. Results

As discussed heart sounds are segmented into S1, S2, systolic and diastolic murmurs. These segments are given to neural network.

Table 1 shows training set used for training of neural network architectures. Number in tables indicated that number of segments used for training. Table 2 shows testing set used for testing of neural network. Accuracy column indicates accuracy using neural networks. Fig 4, fig 5, fig 6 shows regression graphs for given testing dataset which indicates accuracy of particular neural network.

Table 1: Margin specifications

Training Set	AS	MR	MS	AR
S1 (49)	12	13	12	12
S2 (47)	11	12	13	10
Systolic Murmur	15	11	9	3
Diastolic Murmur	7	3	15	13

Table 2: Testing Set

Testing Set	AS	MR	MS	AR	Accuracy
S1 (31)	8	8	7	8	21/31
S2 (31)	8	8	7	8	-
Systolic Murmur	6	7	3	3	16/19
Diastolic Murmur	2	3	9	6	17/21

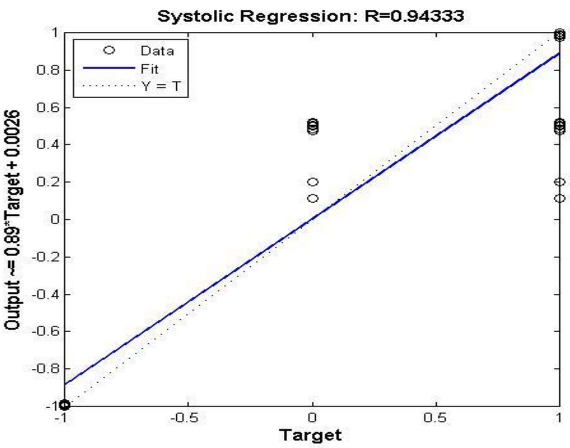

Figure 4: Systolic Murmur neural network's regression graph

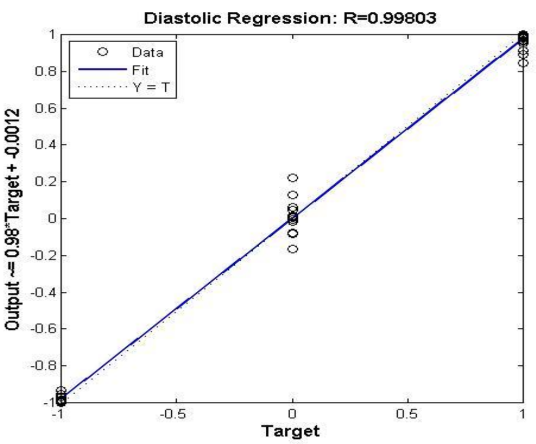

Figure 5: Diastolic Murmur neural network's regression graph

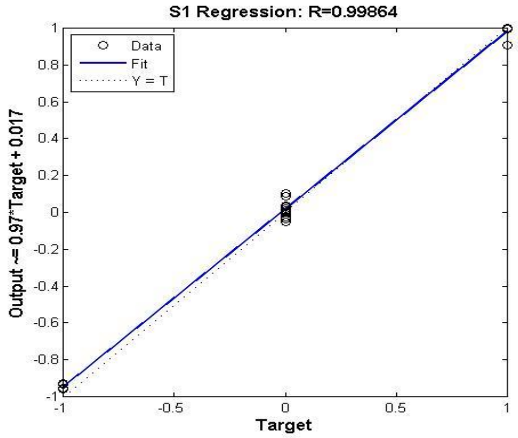

Figure 6: S1 neural network's regression graph

References

[1] S.N. Sivanandam and S Sumathi, *Introduction to Neural Networks using Matlab 6.0*, MC Graw Hill , 2014.

[2] Chrysa D. Papadaniil, Leontios J. Hadjileontiadis, "Efficient Heart Sound Segmentation and Extraction Using Ensemble Empirical Mode Decompositon and Kurtosis features," *IEEE Journal* of Biomedical and Health Informatics, vol. 18, no. 4, pp. 2168-2194, July 2014.

[3] Mahesh C. Shashtry, "An Empirical Mode Decomposition Based Approach For Through The Wall Radar Sensing of Human Technology," Master's dissertation, Dept. of Electrical Eng., The Pennsylvania state Univ., Cambridge, August 2009.

[4] Faizan Javed, P A Venkatachalam "A Signal Processing Module for the Analysis of Heart Sounds and Heart Murmurs," Journal of Physics: Conference Series 34 (2006) 1098–1105

[5] http://home.agh.edu.pl/~vlsi/AI/backp_t_en/backprop.htm l

[6] Jean Claude, Eric delechelle, "Empirical Mode Decomposition: Applications on signal and Image Processing," *Advances in Adaptive Data Analysis*, vol. 1, no. 1, pp. 125-175, 2009.

Author Profile

Ashish Shelke received the B.E. degrees in Electronics & Telecommunication Engineering from Savitribai Phule Pune University in 2012. Now is pursuing M.E. degree in Signal Processing (E&TC) from Savitribai Phule Pune University. His area of interest is signal processing, video processing.

Prof. V. B. Baru is an Associate Professor in Electronics and Telecommunication Department at Sinhgad College of Engineering, Pune. He has done BE in 1993 and completed ME in 1999 in Electronics and Telecommunications. He is pursuing Ph. D from College of Engineering, Pune. He has 20 years of Teaching Experience and published more than 50 papers in national and International level journals. He is author of two books 'Electronic Product Design' by Wiley Publication and 'Basic Electronics' by Dreamtech Publication. He has guided more than 100 UG students and about 25 PG students for their Dissertations