

# Fuzzy Based Early Detection of Myocardial Ischemia Using Wavelets

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**ABSTRACT:** Heart plays a major role in the life of human beings. There is an increase in heart ailment over the years, earlier detection could have avoided many patients suffering from heart disease. Cardiovascular disease such as Myocardial ischemia is the number one leading cause of deaths in united states. Myocardial Ischemia is a heart ailment, where blood flow to the heart is interrupted and not enough oxygen is received by the heart. This paper focuses on an early detection of MI using Discrete Wavelet Transform(DWT) to extract feature vectors, the feaures are then passed through classifiers like KNN and SVM and finally MI detection using fuzzy rules is carried out. Fuzzy rules are used to help predict and understand he outcome of diagnosis, as fuzzy rules are close to human thinking and it helps doctors to understand the decision process of the fuzzy rules. The results show that the proposed work performs 8% better than PCA[1] based model. MLP classifier gave Sensitivity 98.2% , Accuracy 97.5% and PPA 98.56%.

**KEYWORDS:** KNN, SVM, Fuzzy, DWT, Heart Disease, Myocardial Ischemia

## I. INTRODUCTION

ECG is the non-invasive tool that measures and records the electrical activity of the heart. An estimation of World Health Organization 17.7 million people died from cardiovascular disease in 2015 that is 31% of all global deaths. Of these deaths, an estimated 7.4 million are due to coronary heart disease and 6.7 million due to stroke. Heart disease being the most common among the cardiac disorders. One of the cardiac disorder is Myocardial ischemia occurs when the arteries that supplies oxygen to the heart muscle become blocked. Myocardial ischemia is also known as Coronary Heart disease (CAD) in which wax like substance called plaque build up inside the coronary arteries, this condition is called athelerosis. The long time persisting ischemia causes the death of the heart cells which lead a heart attack or MI. Detection of heart beat is necessary to determine the heart related and several other heart related problems such as Tachycardia and Bradycardia and variation in the heart rate. Therefore, the proper detection and processing of ECG is very much important. The ECG is a technique of recording bioelectric current generated by the heart which is useful for denoising many cardiac disorders. Heart beat plays an important role in determining the heart rate and various other heart disorders such as Tachycardia, Bradycardia and variation in the heart rate. Therefore the proper detection and processing of ECG is very important for the detection of cardiac disorders. One cardiac cycle in an ECG signal consists of the P-QRS-T wave. Recently many techniques have been proposed to detect these features includes Artificial Neural Network, Genetic Algorithm, Digital signal analysis, Slope Vector Waveform. As ECG signals amplify by noises and artifacts such as power line interference, electromagnetic intervention, baseline drift removal, and high frequency noises during data acquirement. In this paper wavelet filtering based Daubechies and Symlet wavelet family are used to extract feature vectors and to improve the SNR and minimize MSE of the ECG signals. These feature vectors are then passed through the classifiers like KNN and SVM. Finally we use fuzzy rules to make expert systems and intelligent systems for ischemic episodes detection as these rules are close to human thinking which helps doctors to understand the decision process. Wavelet based method presents best performance for denoising ECG signals and make them suitable for ECG data analysis.

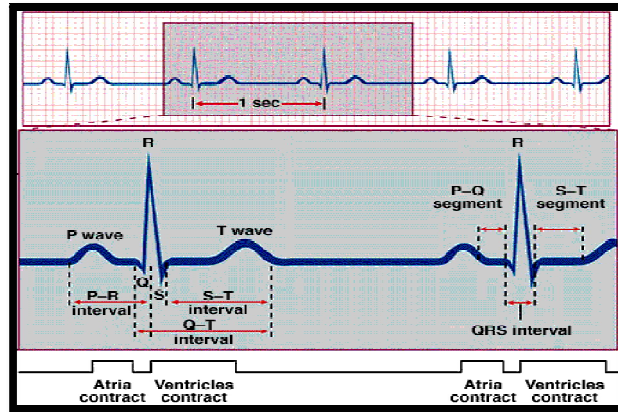


Fig. 1. A Typical ECG Waveform

## II. MATERIALS AND METHODS

ECG data from long term ST-T database, long term ECG database are used. We describe a method for the monitoring of patients from the classification and comparison of ischemic episodes detected by the system. Fuzzy rules are used to predict the outcome of diagnosis and understand it. We designed proposed fuzzy in such a way, which measures the capability of system to transparently reflect its ability to describe symptoms- diagnosis relation in an understandable manner. Before describing the process for comparing ischemic episodes, the first task performed consists of the acquisition of ECG signals. As ECG is exaggerated by noises and artifacts so denoising of ECG is done using wavelet filtering based Debauchies 'and Symlet wavelet family.

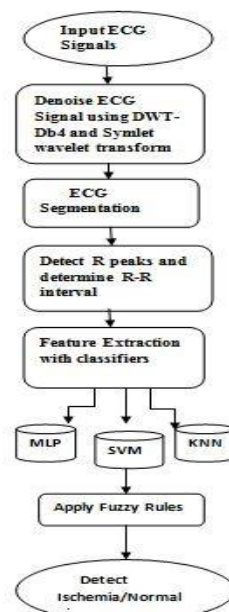


Fig 2. Flow Chart to Detect Ischemia

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## A. Denoising of Signals

### 1. Wavelet Transform

Wavelet transform are similar to Fourier transform, but unlike Fourier transform that is well suited only for the study of stationary signals, where all frequencies have an infinite time. Wavelet transform are used to identify the characteristics points of ECG signals by detecting compact patterns for ischemic events. These characteristics points are then used to detect ischemic episodes. In this proposed method the noisy and corrupted ECG signals are denoised by taking the DWT-Db9 of raw and noisy signals. The wavelet transform performs a correlation analysis, therefore when the input signal most resembles the mother wavelet the output is said to be maximal. This means that shrinking the wavelet transform will remove the low amplitude noise or undesired signal in the wavelet domain.

### 2. Daubechies Wavelet Transform

Daubechies and DWT are a family of orthogonal wavelets. These wavelets have the characteristics of maximal number of vanishing moments that are equal to the half the no. of coefficients. Daubechies wavelets db1-db10 are commonly used. A vanishing moment limits the wavelet ability to represent polynomial behaviour or information in a signal. Denoising involves

1. Decompose signal using DWT-Db9 choose wavelet and number of decomposing levels.
2. Perform thresholding in the coefficient by threshold using Hard and Soft threshold.

Hard thresholding sets any coefficient less than or equal to the threshold zero. It provides better edge preservation. Whereas Soft thresholding reducing coefficient towards zero. If we desire the resulting signal to be smooth, the soft threshold to be used

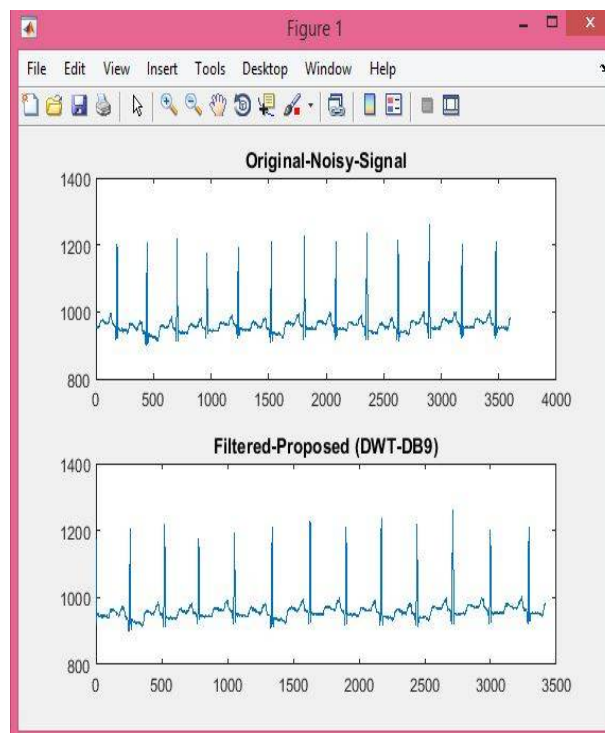


Fig. 3 Denoise ECG signal using DwT-db4

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### 3. Symlet Wavelet

Symlet Wavelet is proposed by Daubechies as modification to the db family. However the properties of two families are similar. In Sym N, N is the order and is nearly symmetrical, orthogonal and biorthogonal wavelets. SNR of denoised signal is improved and it performs better when Symlet are applied to the signals.

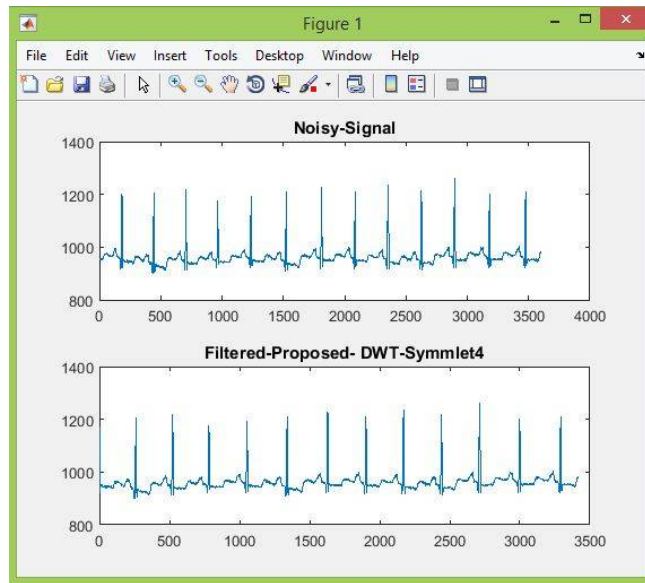


Fig. 4 Denoise ECG signal using Symlet4

### B. ECG Segmentation

Segmenting the ECG signal to determine the different peaks for the detection of ischemia. Peak determines the condition of patient whether the patient has heart rhythm disturbance, angina pectoris (pain in the chest), or other heart problems and most important the ST segment depression and Elevation. ST segment depression and Elevation determines the condition of ischemia. Following GUI shows the different peaks.

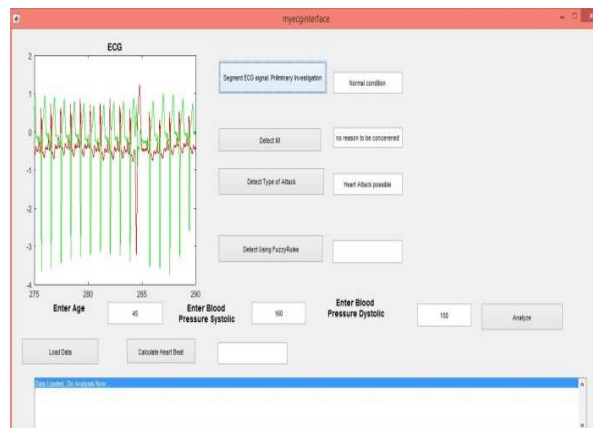


Fig. 5 GUI represents ECG Segmentation

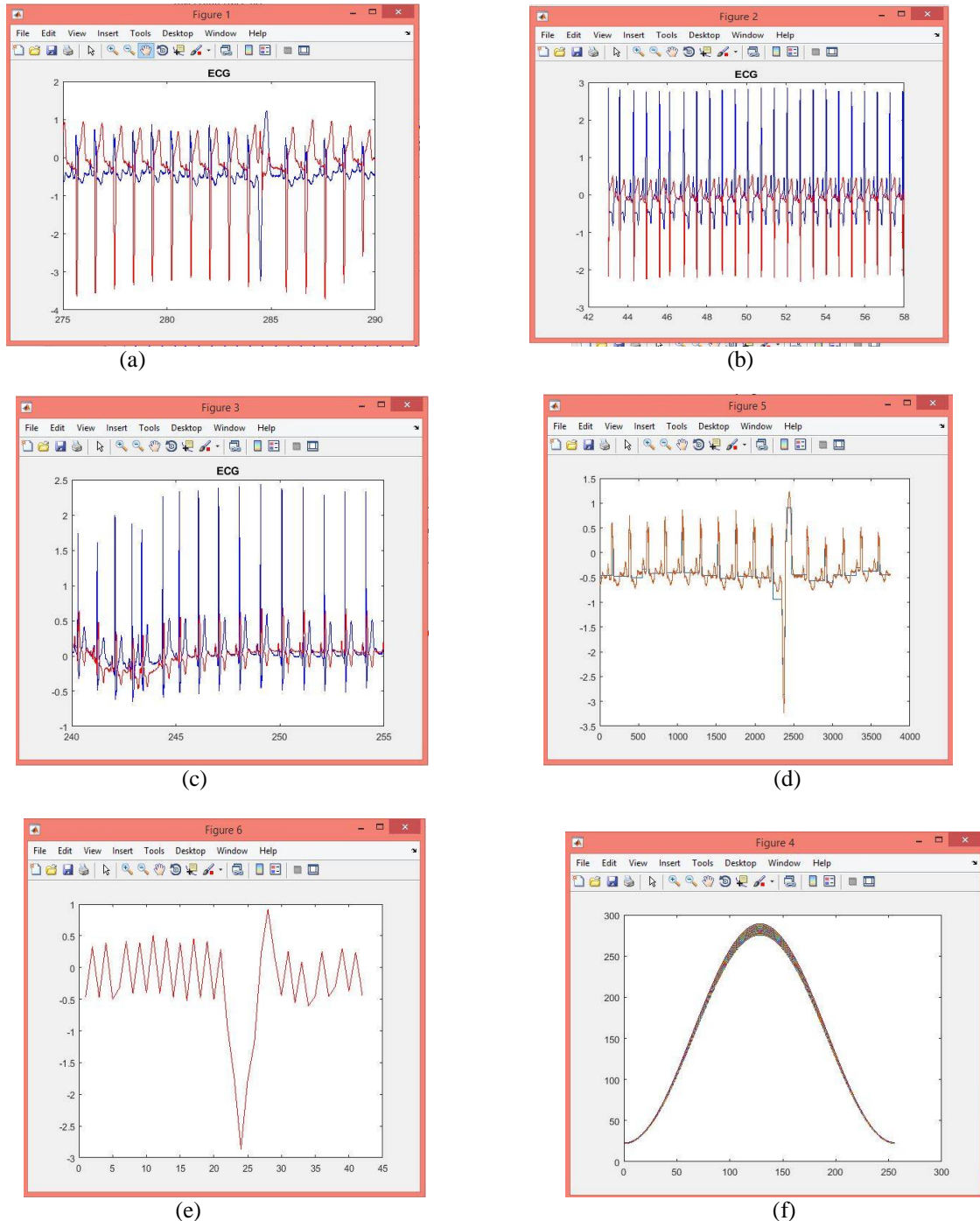


Fig. 6 ECG Segmented Peaks (a) Segmented peak 1 shows ST segment depression (ventricular premature) (b) Segmented Peak 2 shows angina pectoris (pain in chest) (c) segmented Peak 3 shows Deep Q wave which is old MI (d) Segmented peak 4 shows ST segment Depression and baseline MI (e) Segmented Peak 4 shows Rhythm disturbance (below baseline MI) (f) show maximum peak of segmented peaks.



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Figure 6, shows the results of ECG segmentation to determine different peaks in order to detect ischemia in early stages. In segmented peak 1, a deep blue wave shows ventricular premature, ST segment depression and red waves show possibility of Heart Attack. In Segmented peak 2, blue wave show rhythm disturbance, red wave shows attack of chest pain (angina pectoris). A blue wave in segmented peak 3 shows deep Q wave which is old MI. Green and blue wave in segmented peak 4 shows the subendocardial injury and the ST Segment depression.

### III. FEATURE EXTRACTION USING CLASSIFIERS

The feature extraction step is aimed at extracting the abnormal features of ECG beats in consideration of Medical advice. The Extracted features are classified by SVM, KNN and MLP classifiers. Feature extraction is achieved by taking samples between R-R intervals of ECG waves provides clinically useful information of the cardiac conditions. A SVM is algorithm that is used to transform the original training data into a higher dimension using a non linear mapping. Within this dimension it searches for the linear optimal separating hyper plane. One of the advantages of SVM is the need of less training data as compare to other methods. In addition to this errors and complexity can be minimized. KNN is used to compute the distance between the new samples and all previous samples. It selects k samples with the smallest distance values to sort the distances in increasing order. MLP's are most frequently chosen neural network due to their flexibility, configurationality. In the proposed work classifiers used provides 8% better than PCA [1] based model.

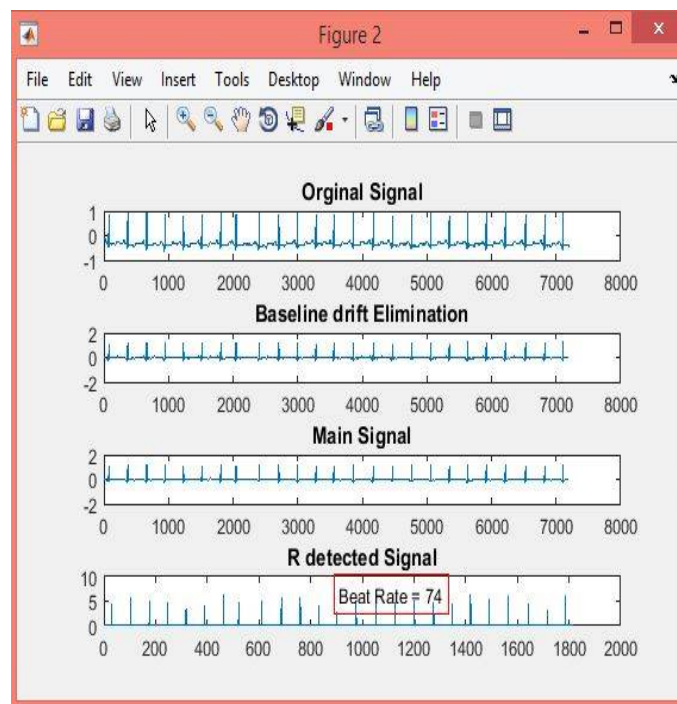


Fig.7 R Peaks Detected

The detection of R peak is the first step of feature extraction. The R-peak has a largest amplitude corresponds to other peaks. Hence amplitude of .5 has been taken as a threshold to detect R peak and finally we detect the R peak location and the difference between two R peaks is the R-R interval with reference to x axis. Once all R peaks are detected then we can easily identified ischemia on the basis of R-R interval. The approximation and detailed coefficient are also plotted using discrete wavelet transform. From the R-peak location R-R interval can be easily estimated that will

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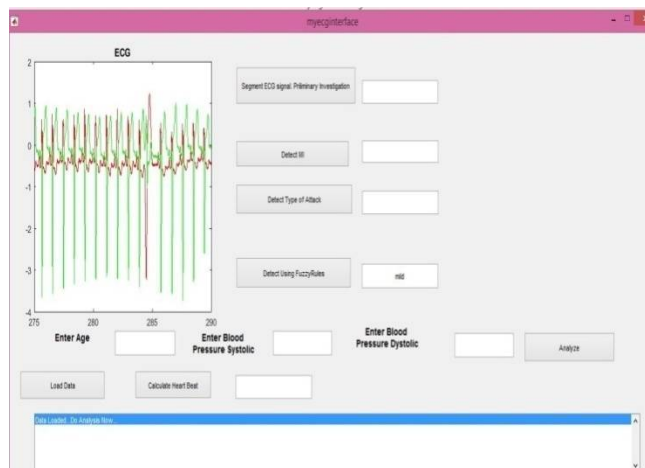
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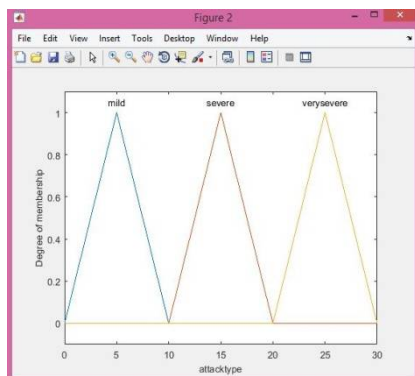
provide best possible heart beats for humans. The main advantage of this kind of detection is less time consuming for long time ECG signal.

## IV. APPLY FUZZY RULES TO FEATURE VECTORS

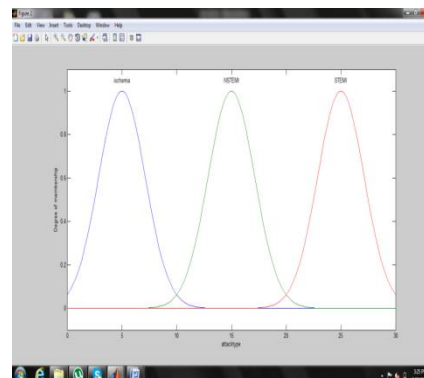
By combining the classification methods with a rule based method, the proposed method provides high sensitivity and accuracy. The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel and the order of rule is unimportant. The rules themselves are useful because they refer to variables and the adjectives that describe those variables. Before we can build a system that interprets rule, we must define all the terms we plan on using rules. The fuzzy rules serve as a basis or the fuzzy dependency and command language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal we can use fuzzy logic toolbox software with Matlab technical computing software as a tool for solving problems with fuzzy logic.



(a)



(b)



(c)

Fig.8 fuzzy based detection of attacks (a) GUI represent possibility of Heart Attacks (b) shows if possibility of attack is more then patient take medication according to the risk level (c) shows type of ischemic attacks.

**V. EXPERIMENTAL RESULTS**

The Proposed technique has been tested with ECG dataset selected from European ST-T datasets of Physionet database. The Debauchies wavelets are used to reduce the noise in the ECG Signal. The maximum SNR is obtained as 51.610222 and the MSE value is obtained as 0.074581.

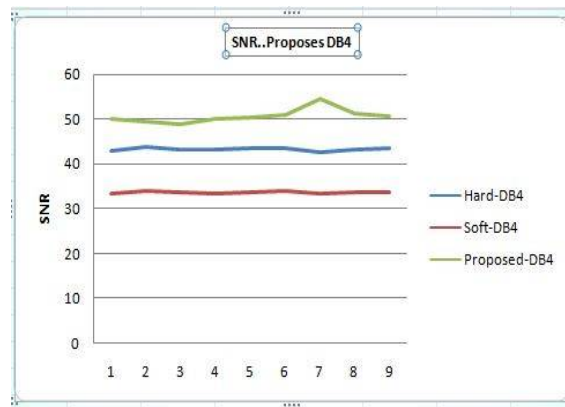


Fig.9 Comparison of Hard, Soft and Proposed of DB4 Technique

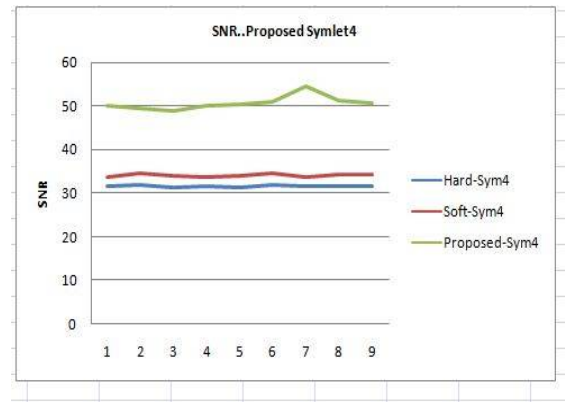


Fig.10 Comparison of Hard, Soft and Proposed of Symlet 4

**TABLE1. Classifiers results of PCA [1] based Model**

Classifier	Sensitivity (%)	Accuracy (%)	PPA (%)
MLP	96.19	90.51	93.8
SVM	78.4	76.6	94.23
KNN	86.43	78.1	88.34



**TABLE II. Classifiers Results of Proposed based models**

Classifier	Sensitivity (%)	Accuracy (%)	PPA (%)
<b>MLP</b>	98.16	97.75	95.72
<b>SVM</b>	80.007	82.72	96.16
<b>KNN</b>	88.20	84.34	90.15

Table I and II shows the results of proposed and PCA based models. The results obtained are better than the existing model. The Accuracy increased by 8% in all the classifiers and sensitivity and PPA also showed an improvement of over 2%.

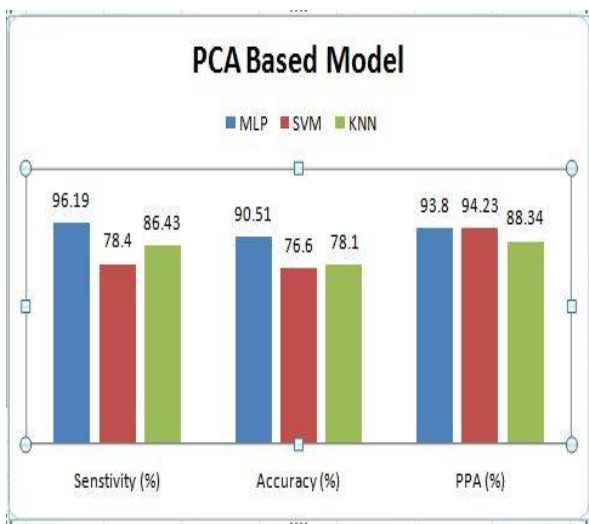


Fig. 11 Performance Comparisons of Classifiers Models of PCA based Model

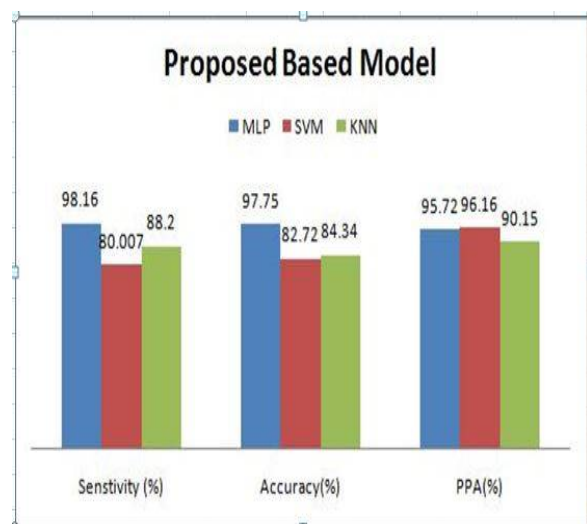


Fig. 12 Performance based analysis of classifiers Models of Proposed based Model

## IV. CONCLUSION

Filtering based Debauchies and Symlet techniques are used for the purpose of denoising of signals. The maximum SNR is obtained as 51.610222 and the average value of MSE in hard and soft threshold is 0.074581. Three classifier models are used for the diagnosis of ischemia showed classification accuracy of 97.5%, PPA 98.56 % and sensitivity of 98.2% which is considerably high in comparison with PCA based model. The symptoms of patient and his diagnosis is expressed using fuzzy rules. Rules are deprived from medical knowledge to detect the ischemic episodes. As an expert fuzzy system is a concept that is much like an expert for a particular problem in humans. It possesses user interaction function which contains an explanation of systems intentions and desires as well as decisions during and after the application has been solved.

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