An Efficient Signal Processing Technique for Automated Myocardial Infarction Detection

M.Hariharan
Assistant Professor Department of ECE,
Muthayammal Engineering College

Vignesh M
Department of ECE,
Muthayammal Engineering College.

Srishoba V
Department of ECE,
Muthayammal Engineering College.

Theerga Aiswarya J
Department of ECE,
Muthayammal Engineering College.

Abstract - Electrocardiography (ECG) is a non-invasive diagnostic tool for diagnosing cardiovascular disease such as coronary artery disease. ECG is a recording of electrical activity of heart lying in mV range so the process of manual detection of heart disease is challenging, consumes time and liable to human errors. Thus an automatic detection of Myocardial Infarction (MI) is done by using single lead (V3) with variable length beat for classifying all eleven classes of MI. In this paper, the Discrete Wavelet Transform (DWT) coefficient's are computed for each heartbeat and after that Principal Component Analysis (PCA) technique is deployed for minimizing the number of coefficients. DWT coefficient's along with PCA is deployed for optimum feature extraction, further Support Vector Machine (SVM) with Radial Basis Function (RBF) kernel is utilized for classification of 11 types of MI and healthy control. The experiment are carried out in MATLAB using PTB ECG diagnostic database. The proposed method gave best accuracy as compared with existing work of 99.02% for classifying 12 classes.

Index Terms—Electrocardiography (ECG), Myocardial Infarction (MI), Discrete Wavelet Transform (DWT), Principal Component Analysis (PCA), Support Vector Machine (SVM).

I. INTRODUCTION

According to the report of World Health Organization [1] around 17.9 million folk died all around the world in the year 2016 because of cardiovascular disease (CVD) that is31% of all deaths. Cardiovascular diseases such as MI and stroke are main reason of death, as it covers 85% of all death that occurred due to CVD. The disease which occurs due to problem in the blood vessels, which give blood supply to the muscle of the heart is termed as coronary artery disease. In coronary artery disease the flow of blood in the artery stops or is blocked due to cholesterol and fatty deposit in the artery. The main cause of artery blockage is atherosclerosis (plaque buildup) because of this, there is restriction in the blood flow to the heart and without sufficient amount of blood the heart starts starving for oxygen this condition is called ischemia. Under this comes Acute coronary Syndrome: This is a syndrome related to coronary artery disease which are: First is Non ST Elevation MI (NSTEMI), In this case there is no major change occurring in the ECG signal but there is change in the cardiac marker. This condition is initial stage when blocking of artery starts. And second one is ST Elevation MI (STEMI), this can be detected both by blood test as well as by ECG signal. There is variation in ST segment becomes elevated this is clearly visible in patients suffering from MI. Electrocardiography (ECG or EKG) is the method through which the electrical activity of the heart is recorded with respect to time by using electrodes placed over the skin.Fig.1 showing one beat of ECG signal. By ECG we can detect as well as localize MI.

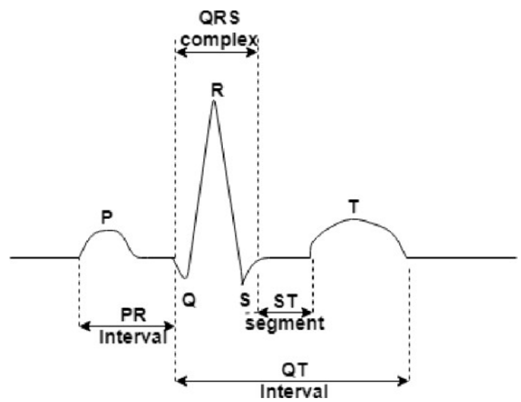

Fig. 1. The ECG signal

There is variation in ST-segment, Q wave appearance and T-wave [2] due to MI therefore, these were used for classification of MI. Acharya et al.[3] in this worked on automated MI detection and localization using all 12-lead ECG by decomposing the ECG signals with discrete wavelet transform up to four level, 12 nonlinear features were extracted from these coefficient and classification was done with k- nearest neighbor (KNN). Arif et al. [4][5] applied KNN and also BPNN classifier forthe diagnosis of MI. For detection of MI, Sharma et al. [6] utilizedthe concept of MEES (multi-scale energy and Eigen space) on ECG leads for identifying and localizing MI by using SVM with RBF kernel. Jayachandran et al. [7] used discrete wavelet transform for MI classification. Principal Component Analysis (PCA) and Optimization algorithms helps to improve the performance [8] with Support Vector Machine classifier. Acharya et al.[11] applied CNN (convolutional neural network) for automatically identifying the MI using ECG signals. Sadhu khan et al.[12] used harmonic phase distributed pattern obtained using Discrete Fourier Transform as input for the classifier which is based on threshold and logistic regression for classification of MI. The remaining paper is arranged as follows: the feature extraction and classification methods which are used are discussed in Section II. In Section III the proposed steps of work done is discussed and in Section IV the discussion of results are done. Finally Section V leads to conclusion of the paper

II. FEATURE EXTRACTION ANDCLASSIFICATION ALGORITHM

A. Discrete Wavelet Transform (DWT)

In wavelet transform the signal is decomposed by means of scaling and shifting of a mother wavelet. Thus, the WT of a signalis obtained by

PROPOSED METHOD AND STEPS

Data Preparation

The ECG database used is from PTB diagnostic available onlineon Physionet. It is a digitized data of 15-leads. Thus, the time resolution is higher at high frequencies than as compared to that of low frequencies. Three level decomposition of DWT is shown in Fig. 2.

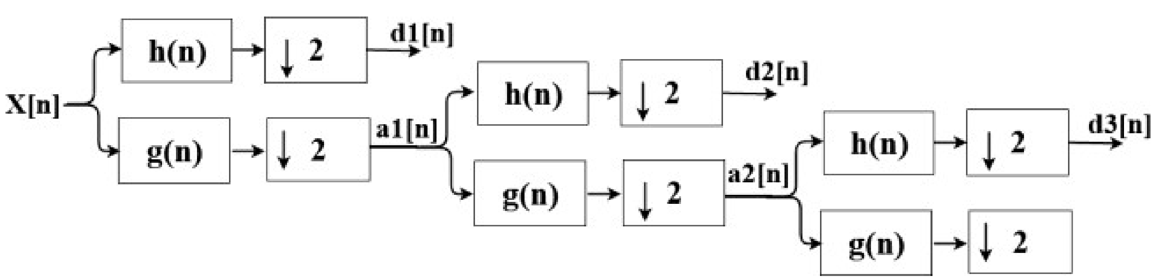

Fig. 2. Three level decomposition of DWT

Principal Component Analysis (PCA)

PCA is an unsupervised learning method used in filtering, compression, feature extraction and dimension reduction. Principal component analysis is a mathematical method whose task is to convert the data of correlated variables into a fewvariables that are uncorrelated i.e. (principal components). The ECG. The data consist of recording from healthy person as well as the patients suffering from various cardiac diseases at the Department of Cardiology, Germany. Sampling frequency of the data is 1000 Hz. Total recording used is 448 among them 79 are Healthy Control records from 52 cases and that of MI are 369 records from 148 cases of MI. MI record is categorized on the basis of heart's specific area damaged, so various type of MI and their total beat is given in Table I.

By using the twelve lead placed over different regions of body the hearts electrical activity are recorded from different angles. Myocardial Infarction produces changes in the morphology of leads according to the blockage occurred in the particular region of heart and opposite variation takes place in connecting lead. Normally in hospitals, all the 12-lead ECG data is being used for detecting and localizing MI. For example, lead III is derived from lead I and II so it is unwanted. However, for a mobile device recording from all the twelve leads will lead to high cost of instrument and it also obstruct the movement of patient. Acharya et al. [3] have achieved

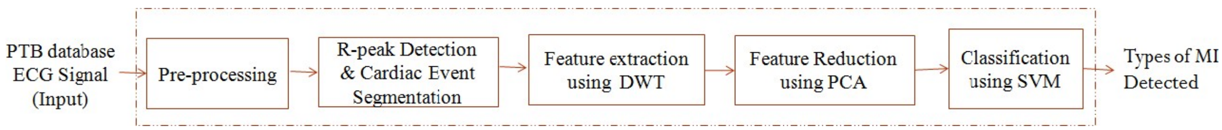

Fig. 3. Proposed Block Diagram for automated detection of Myocardial Infarction

The proposed flow for automated detection of MI is dis- playedin Fig. 3. Block diagram mainly comprises of pre-processing block for removing noise, followed by R-peak detection and segmentation block where R peak is detected in order to segment the beat of different classes having different pattern. Third step is Feature extraction where time-frequency domain features are extracted using DWT and then optimum feature are selected by using PCA and finally followed by SVM classifier for classifying type of MI. The detailed of each subsections are described as follows.

Pre-processing

The first step is pre-processing in which the signal is pre-processed in order to eliminate artifacts from the signal as the rawECG signal is in mV range the noise can distort the signal.

Artifacts for example baseline wander, electrode movement, power-line interference etc. should be removed. The baseline wander is separated using a low pass Butter worth filter and for eliminating from power-line interference notch filter of 50 Hz isused. Thus Pan Tompkins algorithm [14] is applied on the outputECG signal from filter which is having high signal to noise ratiofor finding R-peak.

R-peak Detection and Cardiac Event Segmentation

The segmentation of prepossessed noise free ECG signal intobeats is done by using Pan Tompkins R-peak detection algorithm. The segmentation of prepossessed noise free ECG

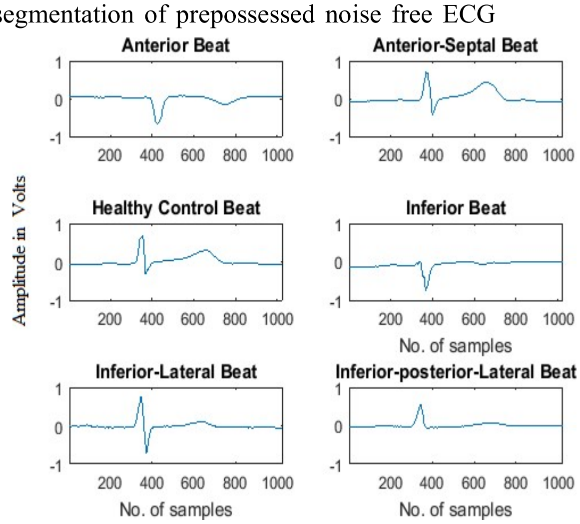

Fig. 5. Lead 9(V3) Beats pattern for Healthy Control andsome classes of MI

Feature Extraction using Discrete Wavelet Transform (DWT)

After segmentation each beat containing PQRST pattern of ECG signal is obtained as displayed in Fig. 5. But as

1024 samples are taken the complexity for training the classifier is very high therefore feature extraction is done. Ten level Discrete Wavelet Decomposition of each ECG beat is done by using Daubechies db4 wavelet. The ECG beat pattern is similar to Daubechies db4 wavelet therefore it is being used here. Thus, resulted in 20 sub band that is 10 for detail coefficients and 10 for approximation coefficients. The sampling frequency of data is 1000 Hz therefore after decomposing [0.5 to 31.5 Hz] band coefficient i.e. six sub-bands (5,6,7,8,9,10) details coefficient are taken for further classification task. The coefficients D5, D6, D7, D8, D9 and D10 are concatenated to determine the final feature vector of length 99.

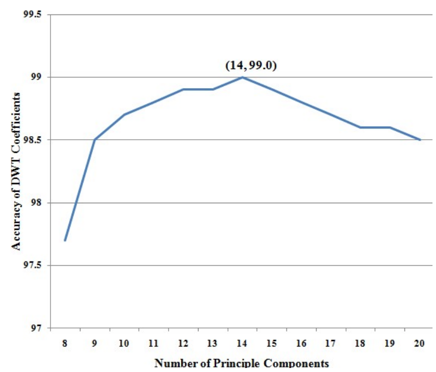

Fig. 6. The variation of accuracy with principle components

Represent the attribute of waveform morphology, are further optimized by applying PCA. In PCA the variance is calculated and arranged in descending order, larger the variance more uncorrelated they are and thus good for classification. Thus time frequency features dimension is minimized as well as the complexity for the classifier is optimized. For selecting the number of principal components (PCs) to be considered, the accuracy for varied number of the PCs for DWT coefficient is calculated. The PC's are varied as shown in Fig. 6 and final no of PC's selected are those, which give maximum accuracy for DWT coefficient. So final feature length input to the classifier which gave maximum accuracy is 14.

Classification using Support Vector machine (SVM)

The SVM with RBF kernel is utilized for classifying twelve classes. Cross validation of tenfold is used which shuffles and splits the data set in 10 groups for overcoming the over-fitting problem. The regularization parameter of the classifier i.e. C is selected by varying the value of C in the scale of [.1, 10], kernel function parameter is kept constant and final C value kept is one. For the multi class classification one against one technique is used for classifying the ECG signals, therefore total 66 classifier are used in this technique as there are twelve classes. SVM with RBF kernel produces good result than poly kernel.

III. EXPERIMENT RESULTS AND ANALYSIS

Performance Evaluation parameter

The performance evaluation is done by calculating following performance parameters for example for Healthy case true positive (TP) denotes the correct classification of the Healthy. True negative (TN) denotes the correct classification of the MI ECG signals, false positive (FP) denotes the misclassification of the MI beats into Healthy signals and false negative (FN) represents the misclassification of Healthy as MI signals. These parameters are utilized for calculating the performance metrics for each type of MI and healthy signal namely, sensitivity(Se),Positive predictive Value(Pp), specificity (Sp) and accuracy where sensitivity shows that in all events, how much percentage is correctly classified, whereas specificity is related to nonevents that are correctly

IV. CONCLUSION

The classification is based on support vector machine (RBF kernel) with the DWT coefficient as features in time-frequency domain which are further reduced by applying PCA for getting optimum feature. Eleven classes of myocardial infarction beats are detected. The selection of final feature length after apply- in PCA is done on the basis of no of principle component which gave maximum accuracy for DWT coefficients. Simulation is done by using single lead with variable length beat and highest accuracy achieved is 99.02% with 14 coefficients for MI localization.

REFERENCES

[1] *WHO*. https://www.who.int/cardiovascular diseases/en.

[2] Naser Safdarian, Nader Jafarnia Dabanloo, and Gho- lamreza Attarodi. “A New Pattern Recognition MethodforDetection and Localization of Myocardial InfarctionUsing T-Wave Integral and Total Integral as Extracted Features from One Cycle of ECG Signal”. In: 2014.

[3] C.Nagarajan and M.Madheswaran - ‘Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter’ - *Journal of ELECTRICAL ENGINEERING,* Vol.63 (6), pp.365-372, Dec.2012.

[4] U. Rajendra Acharya et al. “Automated detection and localization of myocardial infarction using electrocar- diogram: a comparative study of different leads”. In: *Knowledge-Based Systems* 99 (2016), pp. 146–156. ISSN: 0950-7051. DOI: https://doi.org/10.1016/j.knosys. 2016 . 01 . 040. URL: http : / / www. sciencedirect . com /science/article/pii/S0950705116000708.

[5] Muhammad Arif, Ijaz A. Malagore, and Fayyaz A. Af- sar.“Detection and Localization of Myocardial Infarc- tionusing K-nearest Neighbor Classifier”. In: *Journal of Medical Systems* 36.1 (Feb. 2012), pp. 279–289. ISSN: 1573-689X. DOI: 10.1007/s10916- 010- 9474- 3. URL: https://doi.org/10.1007/s10916-010-9474-3

[6] Nagarajan and M.Madheswaran - ‘Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis’- *Iranian Journal of Electrical & Electronic Engineering*, Vol.8 (3), pp.259-267, September 2012.

[7] M. Arif, I. A. Malagore, and F. A. Afsar. “AutomaticDetection and Localization of Myocardial InfarctionUsing Back Propagation Neural Networks”. In: *2010 4th International Conference on Bioinformatics and Biomedical Engineering*. June 2010, pp. 1–4. DOI: 10. 1109/ICBBE.2010.5514664.

[8] C.Nagarajan and M.Madheswaran - ‘Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques’- *Taylor & Francis, Electric Power Components and Systems*, Vol.39 (8), pp.780-793, May 2011.

[9] L. N. Sharma, R. K. Tripathy, and S. Dandapat. “Mul- tiscale Energy and Eigenspace Approach to Detection and Localization of Myocardial Infarction”. In: *IEEE Transactions on Biomedical Engineering* 62.7 (July 2015), pp. 1827–1837. ISSN: 0018-9294. DOI: 10.1109/TBME.2015.2405134.

[10] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, “Perfromance Investigation of T- Source Inverter fed with Solar Cell” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749

[11] E. S. Jayachandran, Paul Joseph K., and R. Acharya U. “Analysis of Myocardial Infarction Using Discrete Wavelet Transform”. In: *Journal of Medical Systems* 34.6 (Dec. 2010), pp. 985–992. ISSN: 1573-689X. DOI: 10.1007/s10916- 009- 9314- 5. URL: https://doi.org/10.1007/s10916-009-9314-5.

[12] S. Raj and K. C. Ray. “ECG Signal Analysis Using DCT- Based DOST and PSO Optimized SVM”. In: *IEEE Transactions on Instrumentation and Measurement* 66.3 (Mar. 2017), pp. 470–478. ISSN: 0018-9456. DOI: 10.1109/TIM.2016.2642758. pii/S0010482518301884.

[13] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash “Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756

[14] C.Nagarajan and M.Madheswaran - ‘Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis’- *Springer, Electrical Engineering*, Vol.93 (3), pp.167-178, September 2011.