A Survey on Myocardial Infarction using Digital Signal Processing Techniques and Algorithms

[1]S.Maheswari, [2]Dr.P.Kannan, [3]Mr. Allan.J.Wilson

[1]PG Scholar, [2]Associate Professor and Head, [3]Assistant Professor
Department of Electronics and Communication Engineering,
Amrita College of Engineering and Technology, Nagercoil, India

***Abstract*: India has witnessed a disquieting rise in heart diseases such as heart attack, stroke and other complications in cardiovascular tract. In USA 7,90,000 Americans suffer from myocardial infarction every year. On the whole, the mortality rate is 70%. Early accurate diagnosis can save millions of life and survivors rate can be increased further. The electrical signals from the heart are measured using ElectroCardioGram (ECG). The ECG signal consists of several noises and baseline wandering and has to be processed to extract the information of each waves such as P, Q, R, S, T and rarely U. For feature extraction and noise elimination signal processing plays a vital role. The main aim of this study is to identify the distractions and deviation in any part of the wave mainly on the ST segment with elevation or prolongation which exactly detects the myocardial infarction. The processed information is useful for clinical study. This paper concentrates on the comprehensive study of various detecting methods and algorithms. It also provides an overview of many eminent approaches till date with its drawback and characteristics. The statistical performance metrics such as specificity, sensitivity and accuracy have also been discussed in this survey.**

***Index Terms*: ECG, Myocardial Infarction, Feature Extraction, Accuracy, Sensitivity and Specificity.**

I. INTRODUCTION

Myocardial infarction is otherwise known as heart attack. It can detect different types of MI. MI occurs due to the blockage of blood to the myocardium is deprived of oxygen to the heart. MI also occurs due to various reason mainly high blood pressure, smoking, diabetes, lack of exercise, obesity, high blood cholesterol. MI is detected using Electrocardiogram in which leads are connected to different parts of the body. The 12 lead ECG is used to classify MI patients into one of the three groups : those who have ST elongation ,T wave inversion and do not have normal wave. The standard ECG uses 12 lead method for detection of heart diseases. The first six leads are called limb leads (I,II,II,avR,avL,avF) and remaining leads are called precordial leads(v1,v2,v3,v4,v5v,v6) which are placed on the pericardium of heart.

II. LITERATURE SURVEY

Muhammad Arif et.al.,(2010) has presented a paper on "Automatic detection and localization of myocardial infarction using back propagation neural networks (BPNN)." It has been proposed for its complexity and high accuracy. They collected data from PTG ECG database which contains 549 records from 294 subjects. It has both patients and healthy records. It concentrates on the time domain features from Q wave, T wave and ST elevation and prolongation. It uses localization techniques for detection of different types of myocardial infarction. The detection method involves two methods namely ECG signal pre- processing and Feature extraction.

The raw signal is processed and it has several stages such as QRS detection and De -lineation, baseline removal and iso-electric level detection. QRS detection is processed using Discrete Wavelet transform (DWT). Baseline wandering is an artifact and hence iso-electric line is not well defined. There are several methods for removal of baseline wandering one such used in this is Cubic Spline based technique. It detects the knots from QRS wave from the reference knots of ECG input signal.

The presence and absence of MI is characterized by different waveforms generated in ECG signal. There are two types of myocardial infarction detected using electro cardio graph namely Q wave infarction and non Q wave infarction which are identified from Q wave amplitude and ST wave elevation and depression respectively. PCA is a reduction technique which is used to transform number of possibly correlated variables into a smaller number of uncorrelated variables. The PCA for this component is 117 dimensional.

The Neural Network based classification is used for the identification of detection and localization. It is done by two methods namely: Detection of MI and Localization of MI. The detection can be of two classes namely healthy and patient(infracted). Neural network uses a input layers, hidden layers and output layers. The hidden layers consist of neurons and there are two hidden layers one contains 30 neurons and other has 15 neurons in number. It is optimized using cross validation method. Artificial neural networks can be used to detect and localize MI but as the MI types increases BPNN will not provide high accuracy and hence more number of time domain features should be developed. This paper provides specificity and sensitivity details of about 99.1% and 97.5%. This paper does not provide a detailed account on other statistical features and frequency analysis of ECG[1].

Swati Banerjee et.al.,(2011) proposed a paper based on “A Classification Approach for Myocardial Infarction using Voltage Features Extracted from Four Standard ECG Leads.” This paper deals with the Anteroseptal myocardial infarction. It is used for extraction of pathological features from V1-V4 ECG leads. The ECG signal is subjected to delineation, baseline wander and denoising. It is based on the classification method of Mahalanobish distance for discrimination of functions from different leads. The ECG signals are collected from PTB diagnosis ECG database.

Some of the earlier algorithms used for feature extraction are matched filters, ECG slope criteria, second order derivatives, wavelet transforms. Wave delineation is done using the following methods Method based on artificial neural network, neuro-fuzzy networks, association rule mining, unsupervised classification technique. But, the methodology used is Discrete wavelet transform (DWT). It is used for non-stationary signals and well defined frequency features can be obtained which helps to identify the QRS complex and T wave for different noises. The R-wave can be calculated by multiresolution approach along with thresholding. The waves are calculated based on the differentiation and slope criteria.

The Mahalanobish distance is used for detection of Anteroseptal myocardial infarction and normal function using clustering classifier. This can also used for the detection of QRS onset and offset points and R wave. The terminologies used here are wavelet transforms which allow different scale translation with different frequency and time localization of signal suits for non-stationary signals. The proposed method has three phases namely feature extraction, selection and classification. The pre-processing phase consists of lead selection and DWT decomposition. The sampling frequency of the ECG data from PTB is 1kHz.The denoising plays a vital role in signal analysis. The different types of noises are power line interface, electrode contact noises, electrosurgical noises, motion artifacts and drift baseline. Dyadic scaling is used for power line interference and electrode contact noise will be in the frequency range of 59.5-60.5Hz. Motion artifacts are caused due to baseline changes and the baseline drift is caused due to the respiration and remaining noises are discarded.

The band selection of QRS complex obtained for finding the coefficients of the DWT decomposition and mapping. An empirical mean value is set as the threshold value and the signal goes beyond the threshold value the deviation in R wave is calculated. The QRS complex wave should not exceed 160ms. The threshold value is 15% mean of absolute amplitude. The R wave can be identified by adding QRS start value and 160ms. All QRS complex waves are calculated by this manipulation. Q and S are detected by slope inversion method. Baseline is the iso-electric line and lies on the area about 80ms of R wave. QRS vector computation is obtained by the summation of Q point, S point and R point. The attenuated R wave and elongation of QRS complex and pointed T wave are the causes for Anteroseptal Myocardial Infarction.

The intended algorithm has positive predictivity and sensitivity of about 99.7% and 99.8% respectively. The discrete wavelet transform (DWT) are used for signal delineation and various frequency identification can be done using multiresolution analysis[2].

Neenu Jacob et.al.,(2015) propounded a paper on “Classification of ECG Beats using Cross Wavelet Transform(XWT) and Support Vector Machines(SVM).” It deals with the analysis and classification of ECG signal using Cross Wavelet Transform and Support Vector Machine. The required wave is obtained by measuring the similarities from two time domain waveforms. The MIT-BIH arrhythmia is the database used as a test material and has 47 subjects tested at 48 half period. The sampling frequency of the signals is 360Hz.

The cross wavelet transform (XWT) is used for the classification and analysis by wavelet coherence and wavelet spectrum. It decomposes a signal into components that appears as scales and to study the time domain features. Support Vector Machines is an algorithm used for linearly separable binary sets.

The proposed method is used for two main purposes namely Denoising and Segmentation of beats. Denoising can be done using Discrete wavelet Transform for decomposition and reconstruction. Selection of frequency bands are used for baseline wandering. Thus, R wave peak can be identified. The segmentation of beats is measured based on extraction parameters such as WCS and WCOH by generation of matrices. The SVM is used for classification of layers and it gets separates by a hyperplane that maximizes vectors between two classes. The separation margin is trained to provide two different components. It removes the noises and baseline wandering of the signal. The sensitivity and specificity are 89.5% and 96.4% for SVM based classification. The disadvantage of this system is poor accuracy due to combined uncover classification[3].

Marcio Jose da Silva(2015) proposed a paper on “Characterization of QRS Complex in ECG Signals Applying Wavelet Transform.” It concentrates on filtering process in ECG signals. The normal heart beat rate is 60-100 beats per minute. The continuous wavelet transform is a function of signal multiplied by a scale from mother wavelet. For the filteration discrete wavelet transform are owned and multiresolution to analyse the multiple frequency bands. It is probably used to remove noise using low pass and high pass filters. The major flaw is an Iterative process since it uses multiresolution analysis for discrete signals and continuous wavelet transform for stationary signals[4].

Abhijit Bhattacharyya et.al., trotted a paper on" A Novel Approach for Detection of Myocardial Infarction from ECG Signals of Multiple Electrodes." The algorithms used are Fourier Bessel Series based empirical wavelet transform (FBWT-EWT) and deep layer least square support vector machine (DL-LSSVM).Each signal is divided into nine sub bands and also to analyses the statistical features such as kurtosis, skewness and entropy. Neural algorithm and wavelet transforms approaches are evaluated in the system.

Some of the earlier techniques for learning algorithms are K-nearest neighbour (KNN), support vector machine (SVM), artificial neural network (ANN), and neuro-fuzzy system for the detection and classification of MI. The segment samples have been extracted from Physikalisch Technische Bundesanstalt (PTB) diagnostic ECG database. The features of this technique are ST segment and rough set. It firmly matches two narrow bands and has high spectral resolution. The neural networks in use for cardiac signals are convolution and deep learning algorithm.

The process has two phases: Segmentation and Decomposition. The data are collected from standard 12 lead ECG and the leads are v1,v2,v3,v4,v5,v6,avR,avL,avF,I,II,III.The filtering is carried out using second order butter-worth filter with high pass filter with cut-off frequency 0.5Hz.Segmentation is done using rectangular window 4000x12.FBSE-EWT are used for the filtered signal with its specific corner frequency. The time scale decomposition is specifically for non-stationary signals based on adaptive filter bank structure. It is also applied for separation of multicomponent to mono component signals.

The statistical features such as kurtosis, skewness and entropy are calculated from the ST segment and T wave morphology from each sub band signal for each lead. The DL-LSSVM has input layer, two hidden layers and output layer. The first layer output is fed to second layer as input. It recognizes each digit as pixels. It has number of neurons and each hold a grey scale value 0 and 1. The input layer consists of 784 neurons and each second layer has 16 neurons and are interconnected to each other and total number of activation are 13002 biases. Thus, the statistical features are calculated in terms of accuracy, specificity and sensitivity and Entropy has high efficiency. The elevation or prolongation are taken from the ST segment of 12-Lead ECG signal.

The overall performance of neural classifier is 108 in dimensional skewness. The DNN classifier has high value on entropy and poor skewness and kurtosis. The drawback of deep learning techniques such as deep belief network and convolution neural network can be used for different categories classification in sub band signals[5].

Selva Nidhyananthan et.al., (2016) developed a paper on "Myocardial Infarction and Heart Patient Identity Verification." It is based on Daubechies wavelet transform and is decomposed into different sub bands. The variations in the PQ interval , QRS complex and inversions in the ST segment occurs in a patient signal. The observations are made by variation in the different values of energy and eigen values in the structure of multiscale matrices. Classification is done using SVM classifier. The samples are collected from PTB database.

The proposed method had three different types: Pre-processing, Feature extraction and Classification. The pre-processing involves filtering followed by segmentation process. Smoothing is done to remove noise and baseline wandering. The feature analyses are used to detect the values of eigen space, energy and wavelet transform. The mentioned wavelet transforms are used to split the signals and decompose them into sub bands coefficient in the standard 12-lead ECG signal. This analysis the energy present in the sub band coefficients with different mean and variance values calculated. The variation in the eigen values can be calculated for eigen space which appears as a numerical value. The binary SVM is used for MI and Pan Tompkinson Algorithm detection specifies the changes in the RR interval. The one of the statistical parameter accuracy has 90.42%. The limitation is only RR internal estimation and accuracy is poor[6].

Aykut Diker, Subha Velappan et.al.,(2018) introduced a paper on Intelligent system based on genetic algorithm and support vector machine for detection of Myocardial infarction from ECG signal. It aims at diagnosing ECG signals using morphological time domain and discrete wavelet transform and to verify SVM and genetic learning algorithm is used. The data were collected from PTB database.

After the data from database are selected based on the healthy and patient pre-processing is performed to remove noise, baseline wandering and power line interference. A median filter is used for softening. The Pan Tompkins algorithm identifies the intervals and mainly peak characteristics of R wave and all other statistical features were taken in account. The raw signal is again decomposed by discrete wavelet transform to represent the signal in sub bands. The support vector machine is efficient in elimination of regression and classification of signals. The supervised learning algorithm such as genetic algorithm was introduced which divided the signal into hyperplane and at the margin number of support vectors are used to classify the signal with different layers.GA is the process of obtaining the best value among the randomly generated population of data sets. Using GA the dimensions of the extracted features were decreased further from 23 to 9. The values of performance metrics such as specificity, sensitivity and accuracy were 88.67%,86.97% and 87.8% respectively[7].

Chih-Sheng Huang et.al.,(2011) developed a paper on "VectorCardioGram-based Classification System for the Detection of Myocardial Infarction." VCG is another type in detection of heart diseases that represents the magnitude and direction of vector signal in space. It requires proper feature extraction between patient and healthy. The T wave in VCG can be detected by three steps : Maximal angle between RT and QRS wave ,T-axis EDA and Ratio of maximum to mean T vector magnitudes. Inferior myocardial infarction can be detected frontal and superior deviation and maximal inferior deviation. The signals are pre-processed and segmented at its first 6 seconds. From the QRS complex and T wave, 64 features has been extracted and not all is significant for classifier algorithm and Sequential backward and sequential forward algorithms are used for feature selection. The 448 ECG signals are taken from the PTB database using maximum-likelihood, general linear mode and two non-parametric classifiers and sampling methods such as k-fold cross validation for sampling the sub band signals. This provide effective classification and feature extraction of different signals and it measures the positive predictive provides high efficiency. The sensitivity, specificity and accuracy are 99.89%,92.51% and 96.96% respectively. The major drawback is number of classifiers are used and iterative in nature[8].

Chun-cheng Lin et.al.,(2015) asserted a paper on “Wavelet Based High Frequency Analysis of Fragmented QRS Complexes in Patients with Myocardial Infarction.” It is used to find the high frequency components in the signals. The continuous wavelet transforms are used translate the wave into different time domain characteristics and the wave gets divides from the time domain functions of mother wavelets. The fragmented QRS complex wave has a mean sensitivity and mean specificity were 60% and 65% respectively. The major flaw detected is it produces very low sensitivity[9].

Nivitha Varghees and K.I.Ramachandran pointed out a paper on “Effective Heart Sound Segmentation And Murmur Classification Using Empirical Wavelet Transform And Instantaneous Phase For Electronic Stethoscope”. It concentrates on murmur classification and signal delineation. The measurement is done using PhonoCardioGram (PCG) and Empirical Wavelet Transform is used for feature extraction. Shannon Entropy is used for background noise removal. The data extracted from PCG database including physionet and PASCAL Heart sound challenge. PCG is an electronic recording of heart vibrational activity. The EWT is used for the attenuation and suppression of motion artifacts, baseline wandering and high frequency noises. The Shannon entropy is used for peak amplification without reference signal for computation. Smoothing filter is used for attenuating the local peak signals and its noises. To detect number of patient and healthy signals were taken and evaluated based on the signal transforms mentioned above. The amplitude threshold value set is 0.01. This technique improves versality and robustness. The performance metrics such as sensitivity and accuracy were 97.58% and 94.21% respectively [19].

III. CONCLUSION

In this literature survey, number of techniques and algorithms used till date were discussed and diagnosing of myocardial infarction is very important in clinical study. This paper provides an overview of ECG signal filtering and signal processing with in depth evaluation of feature extraction, noise removal and support vector machine techniques. While recording ECG signals number of noises such as powerline interferences, baseline wandering and different artifacts can be removed using different wavelet transforms and the accurate prediction of deviation and distractions in any one of the wave can be detected using different support vector machines. General approach used in all signal processing consists of pre-processing, segmentation or segregation and denoising and support vector machines are used for the classification and post-processing. From the overall study, the time frequency based approach provides finer performance in cardiovascular diseases and wavelet based features are used for classification. The different types of performance metrics such as accuracy, specificity and sensitivity were analysed from each paper and the reading were mentioned above.

IV. SUMMARY:

Sl.no	ECG	ALGORITHM	SUPPORT VECTOR MACHINE	PERFORMANCE METRICS			DETECTION
				ACCURACY	SPECIFICITY	SENSITIVITY	
1.	12 Lead	Discrete Wavelet Transform	Back propagation neural network	-	99.1%	97.5%	QRS wave
2.	4 lead	Discrete Wavelet Transform	-	99.7%		99.8%	R wave
3.	12 lead	Cross wavelet Transform	-	poor	96.4%	89.5%	R wave peak
4.	12 lead	Discrete Wavelet Transform	-	-	-	-	Filtering process
5.	12 lead	Fourier Bessel Series	Deep Layer Least Square Support Vector Machine	99.74%	99.60%	99.87%	ST segment

6.	12 lead	Daubechies wavelet Transform	Binary Support Vector Machine	90.42%	-	-	RR interval
7.	12 lead	Discrete Wavelet Transform	Genetic Algorithm	87.8%	88.67%	86.97%	R and ST segment
8.	VCG	Wavelet transform	-	96.96%	92.51%	99.89%	T wave and QRS complex
9.	12 lead	Continuous Wavelet Transform	-	-	60%	65%	Elimination of high frequency waves.
10.	PCG	Empirical Wavelet Transform	-	94.21%	-	97.58%	Heart sound and murmurs

Abbreviations and Acronyms

ANN	-	Artificial Neural Network
CNN	-	Convolutional Neural Network
DBN	-	Deep Belief Network
DESA	-	Discrete Energy Separation Algorithm
DFT	-	Discrete Fourier Transform
DL-LSSVM	-	Deep Layer Least Support Vector Machine
DNN	-	Deep Neural Network
ECG	-	ElectroCardioGram
EWT	-	Empirical Wavelet Transform
FBSE	-	Fourier Bessel Series Expansion
FV	-	Feature Vector
HC	-	Healthy Control
HL	-	Hidden Layers
HT	-	Hilbert Transform
KNN	-	K Nearest Neighbor
MI	-	Myocardial Infarction
PCG	-	PhonoCardioGram
PTB	-	Physikalisch Technische Bundesanstalt
SVM	-	Support Vector Machine
VCG	-	VectorCardioGram
WT	-	Wavelet Transform
WVD	-	Wigner Ville Distribution
BPNN	-	Back Propagation Neural Network
MIL	-	Multi Instance Learning

Authors and Affiliations

[1]S.Maheswari, [2]Dr.P.Kannan, [3]Allan.J.Wilson

[1]PG Scholar, [2]Associate Professor and Head, [3]Assistant Professor
[1,2,3]Department of Electronics and Communication Engineering,
[1,2,3]Amrita College of Engineering and Technology, Nagercoil, India

V. ACKNOWLEDGMENT

I thank the Principal of Amrita college of Engineering and Technology, Prof.Dr.R.K.Suresh, M.E., Ph.D., PGDMM for his encouragement and constructive ideas. I wish to extend my thanks of gratitude to Dr.P.Kannan, M.E, Ph.D, Head of the Department, Electronics and communication Engineering and Mr.Allan.J.Wilson, M.E., (Ph.D) for their immense support and guidance without which this work would not have been completed.

REFERENCES

[1] Mohammed Arif and Ijaz.A.Malagore,Fayyaz.A.Afsar,"Automatic Backbone Detection and Localization Of Myocardial Infarction Using Back Propagation Neural Networks",IEEE 2010.

[2] Swati Banerjee and Madhuchhanda Mitra,"A Classification Approach For Myocardial Infarction Using Voltage Features Extracted From Four Standard ECG Leads", International Conference On Recent Trends In Information Systems, IEEE 2011.

[3] Neenu Jacob and Lisa Annie Joseph," Classification Of ECG Beats Using Cross Wavelet Transform And Support Vector Machines", Recent Advances In Intelligent Computational Systems(RAICS) IEEE 2015.

[4] Marcio Jose da Siliva,"Characterization Of QRS Complex In ECG Signals Applying Wavelet Transform",International Conference On Mechatronics, Electronics And Automotive Engineering,IEEE 2015.

[5] Rajesh Kumar Tripathy,Abhijit Bhattacharyya and Ram bilas Pachori,"A Novel Approach For Myocardial Infarction From ECG Signals Of Multiple Electrodes",IEEE 2018.

[6] S.Selva Nidhyananthan,S.Saranya,R.Santha Selva Kumari," Myocardial Infarction Detection And Heart Patient Identity Verification", Conference on IEEE WISPNET 2016.

[7] Aykut Diker,Zafer Comert,Engin Avci,Subha Velappan,"Intelligent System Based On Genetic Algorithm And Support Vector Machine For Detection Of Myocardial Infarction From ECG Signals",IEEE 2018.

[8] Chih-Sheng Huang,Li-Wei Ko,Shao-Wei Lu,Shi-An Chen and Chin-Teng Lin,"A Vector Cardiogram Based Classification System For The Detection Of Myocardial Infarction",33rd Annual International Conference Of The IEEE EMBS Boston, Massachusetts USA,IEEE 2011.

[9] Chun-Cheng Lin,Weichih Hu,Yu-Wei Lin,"A Wavelet Based High Frequency Analysis Of Fragmented QRS Complexes In Patients With Myocardial Infarction",Computing In Cardiology 2015.

[10] Mohammed Tali Almalchy, Nirvana Popescu," Noise Removal From ECG Signal Based on Filtering Techniques", IEEE International Conference On Control Systems And Computer Science 2018.

[11] Muhammad Abrar ,Waleed Elahi Khan, "Digital Filtering Techniques For Power-Line Interference Removal From ECG Signals ", Conference On Information Communications Technology And Society (ICTAS) 2018 .

[12] Abdulmalik A, Al-Shoshan ,"Noise Elimination Of Electrocardiogram Signals Using Evolutionary Spectrum ",IEEE 2018

[13] Brij N.Singh,Aravind Tiwari,"Optimal Selection of wavelet basis function applied to ECG signal denoising",Elsevier 2006.

[14] S.T.Sanamdikar, Dr.S.T.Hamde, Dr.V.G.Asutkar,"A Literature Review on Arrhythmia Analysis of ECG Signal", International Research Journal Of Engineering And Technology (IRJET) e-ISSN: 2395-0056, Volume: 02 Issue: 03 | June-2015.

[15] S. Ansari, N. Farzaneh, M. Duda, K. Horan, H. B. Andersson, Z. D. Goldberger, B. K. Nallamothu, and K. Najarian, "A Review of Automated Methods For Detection Of Myocardial Ischemia And Infarction Using Electrocardiogram And Electronic Health Records," IEEE Reviews In Biomedical Engineering, vol. 10, pp. 264–298, 2017.

[16] Mohit Kumar , Ram Bilas Pachori and U. Rajendra Acharya"Automated Diagnosis of Myocardial Infarction ECG Signals using Sample Entropy in Flexible Analytic Wavelet Transform Framework"Entropy 2017, 19, 488; doi:10.3390/e19090488 .

[17] Sardar Ansari , Negar Farzaneh, Marlena Duda , Kelsey Horan, Hedvig B. Andersson , Zachary D. Goldberger, Brahmajee K. Nallamothu, and Kayvan Najarian, "Review of Automated Methods for Detection of Myocardial Ischemia and Infarction Using Electrocardiogram and Electronic Health Records", IEEE reviews in biomedical engineering,vol. 10, 2017 .

[18] Jan Kubicek ,marack penhaker,Radana kahankova,"Design Of A Synthetic ECG Signal Based On The Fourier Series",IEEE 2014.

[19] V.Nivitha Varghees and K.I.Ramachandran,"Effective Heart Sound Segmentation And Murmur Classification Using Empirical Wavelet Transform And Instantaneous Phase For Electronic Stethoscope",IEEE 2016.

[20] Pawel S Kostka and Ewaryst J Tkacz,"Rules Extraction Insvm And Neural Networks Classifier Of Atrial Fibrallation Patients with Matched Wavelets as a Feature Generator", 31st Annual International Conference IEEE 2009.