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Characterization of ST-Segment using Wavelet transforms & Support vector machine

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Abstract—Electrocardiogram (ECG) is used for the electrical recording of the heart signal. In this paper, filtering techniques are used for the removal of baseline wander noise, power-line interference noise etc. from the ECG signal. Cardiac arrhythmia detection is very useful for the cardiologist for effective diagnosis of heart functions using ECG. ECG signal analysis involves various techniques for accurate delineation of characteristics points and then classification of heart diseases using these characteristics points in terms of positive predictivity and sensitivity. Support vector machine is used as a classifier to delineate QRS complex.We have reviewed the available techniques for cardiac arrhythmia detection and feature extraction in literature in terms of accuracy and sensitivity. In this paper, the European database is used for the evaluation of the ST segment. The proposed methods comprise steps such as signal pre-processing, denoising, QRS complex detection and SVM as a classifier.

Keywords— ECG signal, Wavelet Transform, Pan-Tompkins algorithm, Support Vector machine.

I. Introduction

Electrocardiogram (ECG) is basically the electrical recording of the heart signal with the help of electrodes [1]. According to the survey conducted by the World Health Organization (WHO) many of the people died from cardiovascular diseases [2]. Arrhythmia is one of the most frequently occurring abnormalities of the heart. Ischemic heart diseases constitute one of the most common fatal diseases in the world. Ischemia is caused by lack of sufficient blood flow to the contractile cells results in heart failure, arrhythmia and death [3]. Heart is the most important organ of human body which consists of four chambers (two lower chambers and two upper chambers). ECG records the electrical signal of the heart with the help of electrodes. Electrodes are placed on the body of the patient and further connected with the ECG machine. There are five types of waveforms such as P, Q, R, S, T present in an ECG signal in which P wave represent the depolarization, T wave is the repolarization of the ventricles and QRS complex represents the ventricular contraction. PR interval, PR segment, ST segment, QT interval and the QRS complex are the most important regions in the electrocardiogram (ECG) signal.

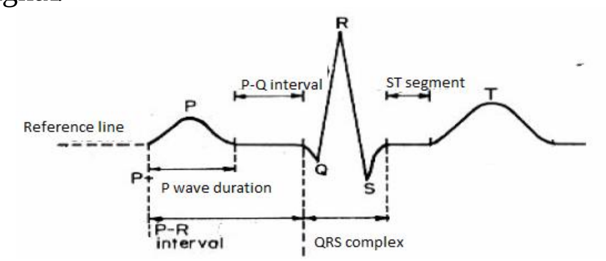

Figure 1 normal ECG signal waveform

The ischemia diseases are usually identified in the standard ECG by change in the value of the amplitude and ST-T complex duration. The pattern of the waveforms changes due to the abnormalities of the heart. ECG signal waveform mainly consists of these types of noises such as baseline wander noise, power line interference noise, muscles noise. These noises affect the quality and sensitivity of the received waveform. The baseline is the isoelectric line from the heart. It is the line that would be observes on an ECG signal. This line is often horizontal because the patients do not move & the signal is not disrupted by external noise. Due to the baseline wander noise, the detection of QRS complex will be more difficult. It also occurs when the ECG machine is not properly grounded. Power line interference noise is present in frequency range from 50 to 60 Hz. The figure 1 represents the normal ECG waveform. The ECG can be classified as normal and abnormal signal. When the ECG is abnormal it is called as Arrhythmia. The heart diseases are mainly classified as Tachycardia, Bradycardia, Atrial Fibrillation, ischemia, myocardial infraction, ectopic beats, arrhythmia etc. When the heart beat rate is less then 100 beat per minute then it is termed as Tachycardia and if it is less then 60 beat per minute then it is called as Bradycardia. The normal human beat rate is between 60-100 beat per minute.

To detect the QRS complex and for the classification of the ECG signal some authors [4,5] used the extreme learning machine instead of Support Vector Machine for the optimum detection of parameters and compare the results with the existing techniques such as artificial neural network [6], fuzzy logic etc.

In the bi-spectral technique for quantitative analysis, the frequency support of the bi-spectrum is extracted as a quantitative measure to classify a trial and ventricular tachyarrhythmias. A significant difference in the parameter values for different arrhythmias is observed in the result. The simplicity of the classification parameter and the obtained sensitivity and specificity of the classification scheme reveal the importance of higher order spectral analysis in the classification of life threatening arrhythmias.

In [7] the author develops the design of a reliable system for detection of the premature ventricular contraction (PVC) from the normal beats and other heart diseases. As the classifier, support vector machine with different kernels, neural network are used. The results show that best results are achieved about 97.14% for classification of ECG beats.

A novel embedded mobile ECG reasoning system [8] is used to integrate ECG signal reasoning and RF identification together to continuous monitoring and identification of the elderly patient. In [9], the author present the fuzzy support vector machines based on fuzzy c-means clustering. They apply the fuzzy c- means clustering method to each class of the training set. At the time of the clustering with a suitable fuzziness parameter q, the much important samples, such as support vectors, become the cluster centers respectively.

Some authors [10], used the concept of Linear Predictive Coefficients, Linear Predictive cepstral coefficients techniques for the extraction of parameters from the ECG signal. It increases the accuracy in the detection of heart disease up to 93.5%. In [11], amplitude parameters are extracted with the help of various filter techniques. The accuracy is calculated for the different heart disease such as tachycardia, bradycardia etc separately.

To detect the ECG samples of the various diseases some authors [12] have used the wavelet transform with Mother Wavelet Daubechies for the removal of noise and for feature extraction. The highest accuracy obtained equals to 98.8%.

So the researcher’s concentration is to find a reliable detection technique using ECG for the patient monitoring. So ECG is an effective and low cost method to determine the abnormalities of the heart. There are basically four processes used for the accurately detection of the heart diseases. This paper deals with developed techniques for the classification of heart diseases in terms of accuracy, sensitivity, and predictivity.

II. MATERIALS AND METHODS

For the accurate detection of heart diseases using ECG, it is necessary to first remove the effects of noises such as power line interference, baseline wonder noise, muscles noise by adopting various techniques like as wavelet transform, notch filter, and high pass filter. Figure 2 represent the flow chart diagram of ECG classification. This paper is organized into three stages, first stage introduces the ECG and types of heart diseases and middle stage described the materials and different classification techniques and last stage includes result, conclusion and references. ECG signal classification mainly consists of three stages such as De-noising, Feature Extraction and classifiers. De-noising is used for the removal of unwanted signal, feature extraction [13] is used for the parameter extraction from the received signal through wavelet transform etc. and finally Classifiers are used for the detection of the heart disease through the waveforms.

A. European ST-T Database

The European data base is intended to be used for evaluation of algorithm for the change in the behaviour of ST wave. This is a rich database [14,15] of several hundred ECG recordings, extending over 200 hours. Each recording contains one to three signals and ranges from 20 seconds to 24 hours in duration. Most of the signals have been annotated on beat-to-beat basis. This database contains 48 ECG signals that were recorded between 1975 and 1979 at the Beth Israel Hospital Arrhythmia Laboratory. The recordings were digitized at 360 samples per second per channel with 11-bit resolution over a 10 mv range. This directory contains the entire MIT-BIH Arrhythmia Database. About half (25 of 48 complete records, and reference annotation files for all 48 records) of this database has been freely available here since Physio Net's inception in September 1999. Annotation file contains data information such as data beat, noise, rhythm etc so it is very useful to evaluate ischemic detection algorithm.

B. Signal Preprocessing & denoising

In ECG signal different types of noises are present which affects the accuracy and sensitivity of the received waveform for reliably and accurately detection of heart diseases.

De-noising is basically used for the removal of desired signal from the unwanted noise signal. ECG signal first goes for preprocessing that eliminate the noise from the received signal with the help of various filters such as high pass filter, notch filter and wavelet transform. There are different types of noises present in the ECG signal; the most important noises are baseline wonder noise, power line interference noise which needs to be removing to achieve high accuracy.

Wavelet transform is better as compare to the other methods for the removal of noise. In this paper, we used wavelet transform and the band-pass filter method in order to remove noise. In [16], the author states about the QRS complex detection system by using the wavelet transform for the extraction of desired signal from undesired signal.

C. Wavelet Transform

Wavelet transform has been widely used for the electrocardiogram (ECG) signal segmentation [17]. It gives resolution both in time domain as well as in frequency domain. In [18] the authors explained the use of the Wavelet Transform for the ventricular late potentials (VLP) in the segmented ECG signal. In [19] the author states about the continuous wavelet transform (CWT). The author examines the possibility of data by thresholding of wavelet coefficients.

Wavelets are generated from scaling and translation the Mother Wavelet.

$$\gamma(s,\tau) = \int f(t)\psi^*_{s,\tau}(t)dt$$

$$f(t) = \int\int \gamma(s,\tau)\psi_{s,\tau}(t)d\tau ds$$

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{|s|}}\psi_{s,\tau}(\frac{t-\tau}{s})$$

Where $\psi_{s,\tau}$ (t) are the wavelets and s & τ are scale and translation.

D. Band-Pass Filtering

Band-pass filtering is the cascade form of low-pass filtering and high-pass filtering. Low-pass filter is used for the removal of the high frequency noise such as (power-line interference noise) & high-pass filter is used for the removal of low frequency noise such as (baseline wander noise) present in the ECG signal. The band-pass filter for the QRS detection reduces noise in the ECG signal by matching the spectrum of the average QRS complex.

E. Support Vector Machine

SVM is used to find an optimal separating hyper plane (OSH) which generates a maximum margin between two categories of data; it maps data into a higher dimensional feature space. It is a single layer and highly non linear network based on statistical learning principles. SVM performs this nonlinear mapping by using a kernel function. Generally the pattern are not linearly separable so non linear kernel transform is performed. SVM has become a widely and powerful machine learning method in last few decades and the Gaussian Kernel is the most generally used kernel function [12,10,20]. In [12] the author explains the development of an algorithm for the ECG samples of the various diseases based on the support vector machine. In [10] the author defines the classification techniques and makes comparison with the already existing techniques. SVM was used in making ST segment classification elevated and normal depressed. . In [21,22], the authors explains the audio classification and retrieval by support vector machine and states the minimization of the risk in pattern recognization.

F. QRS points detection by Pan-Tompkins Algorithm

The Pan & Tompkins QRS detection algorithm is based upon the digital analysis of the amplitude, width and slope. The methodology used is that the ECG is passed through the band pass filter, to reduce the noise. Then the filtered signal is passed through derivative, squaring and window integration phases. In [23] the first step the signal is passed through the band pass filter composed by the low pass filter and high pass filter in cascade, in order to reduce the power line interference noise, baseline wander noise etc. the analytic evaluation of the QRS complex is performed by calculating the sensitivity.

Sensitivity (S_E) =TP/ (TP+FN) (1)

And positive predictivity P+ =TP/ (TP+FP) (2)

Where TP denotes true positive, FP denotes false positive & FN denotes false negative detection. An equation (1) & (2) denotes the sensitivity and the positive predictivity.

III. IMPLEMENTATION

ECG signal consists of different types of artifacts which affects the accuracy in arrhythmia detection. Due to the presence of these artifacts the baseline changes its position so a DC offset is used to move the isoelectric line at zero reference level. After that ECG signal is passed through the band-pass filter. In the band-pass filter, the low-pass filter & high-pass filter are connected in the cascade form. Figure 2 shows the proposed method in this paper as follows;

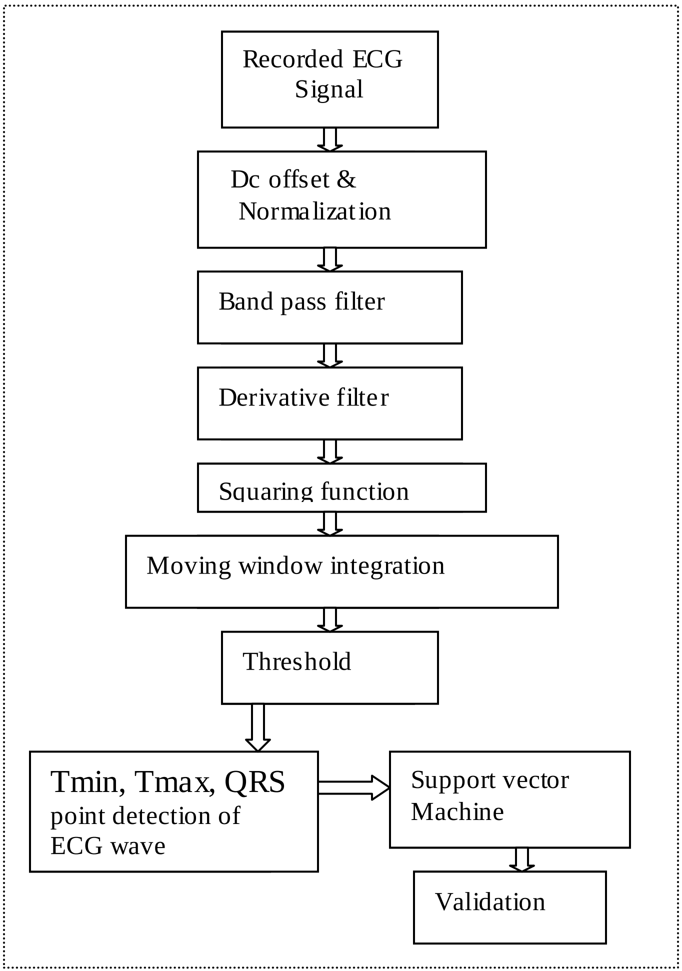

Figure 2 proposed method

a. DC offset Removal & Normalization

DC offset is used to make the isoelectric line at the zero reference. Figure 4 represents the waveform after the DC offset & normalization. The baseline changes the position in the presence of the artifacts & makes QRS complex detection difficult. So DC offset is firstly used to stabilize the position of the isoelectric line.

b. Band-Pass filtering

After the DC offset, band-pass filter is used to remove the low and high frequencies noises present in the ECG signal with the cascade form of low-pass & high-pass filters in figure (5,6). The low pass filter is described by the following transfer function

$$H(Z)_{LPF} = (1-2Z^{-6}+Z^{-12})/(1-2Z^{-1}+Z^{-2}) \quad (3)$$

And the high pass is given by:

$$H(Z)_{HPF} = (-1+32Z^{-16}+Z^{-32})/(1+Z^{-1}). \quad (4)$$

c. *Derivative filter*

After the signal has been filtered, it is then differentiated to provide information about the slope of the QRS complex using the following transfer function. Figure 7 shows the output of the derivative filter.

$$H(Z)_{D.F} = 1/8[2+Z^{-1}-Z^{-3}-2Z^{-4}]. \quad (5)$$

Equations (3), (4) & (5) represent the transfer function of the low pass filter; high pass filter and derivative filter respectively.

d. *Squaring*

The previous processes are the linear processing parts of the QRS detector. The squaring function that he signal now passes through is a non linear operation.

This operation makes all the data points in the processed signal positive, and it amplifies the output of the derivative process nonlinearly in figure 8. It emphasize the higher frequencies in the signal, which are mainly due to the QRS complex

e. *Moving window integration*

Moving window integration extracts features in addition to the slope of the R wave. It is implemented with the following equation. It is used to find out the maximum & minimum values of the QRS points.

$$H(Z) = 1/N\,[Z^{N-1}+Z^{N-2}+\ldots+Z^{N-(N-1)})+1]. \quad (6)$$

Where, N is the number of samples in the width of the integration window. Equation (6) shows the transfer function for moving window integration. It should be the approximately same as the widest possible QRS complex [24]. The width of the window should be approximately the same as the widest possible QRS complex. Figure 9 shows the QRS points detected from the integration method & threshold operation. If the size of the window is too large, the integration waveform will merge the QRS & T complexes together and if the size is small, QRS complex could produce several peaks at the output of the stage.

f. *Thresholding*

After the ECG signal has passed through the band-pass filter stage, its signal to noise ratio increases. This permits the use of thresholds that are just above the noise peak levels. Thus, the overall sensitivity of the detector improves.

g. *Support Vector Machine & Validation*

SVM is used as a classifier in the arrhythmia detection. SVM performs this nonlinear mapping by using a kernel function. Generally the pattern are not linearly separable so non linear kernel transform is performed. It is used to obtain the normal & the abnormal conditions in the heart patients with high accuracy and sensitivity (figure 10).

IV. RESULTS AND DISCUSSION

The validation for the ST-Segment classification was carried out using European ST database. In order to validate, the proposed algorithm was run on different types of ECG records to obtain the normality and abnormality condition. The advantage of the proposed method is its ability of making the noise reduction, QRS points detection with the help of wavelet transform and support vector machine. The sensitivity and positive predictivity achieved from proposed method is better then the other methodologies [25]. Table 1 shows the sensitivity and positive predictivity for the different ECG records such as e0103, e0104 etc.

Sr. no	ECG record	QRS wave	T wave	Sensitivity (%)	+ve predictivity (%)
1.	e0103	1990	1990	100	100
2.	e0104	1974	1974	100	100
3.	e0105	1984	1984	100	100
4.	e0106	1987	1987	100	100
5.	e0108	1982	1982	100	100
6.	e0110	1981	1981	100	100
7.	e0111	1988	1988	100	100
8.	e0113	1992	1992	100	100
9.	e0114	1991	1991	100	100

Table 1 sensitivity & predictivity obtained from proposed method

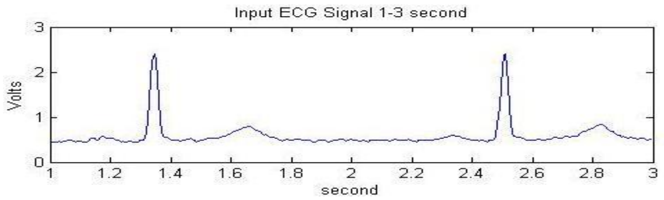

Figure 3 original ECG signal

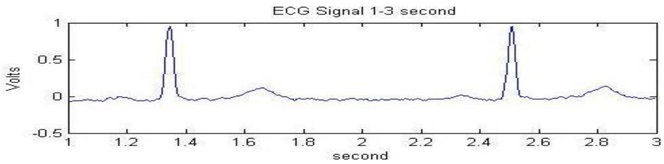

Figure 4 Dc offset & normalization

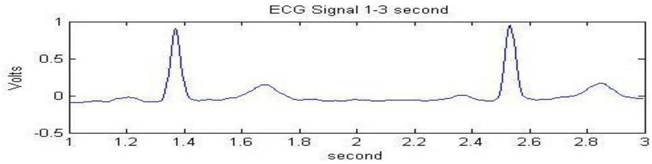

Figure 5 Low-Pass filtering

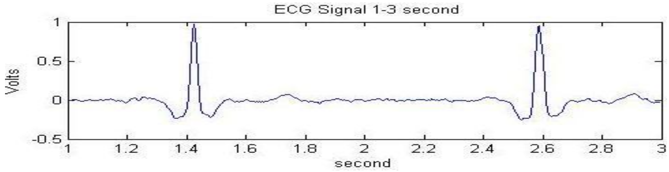

Figure 6 high-pass filtering

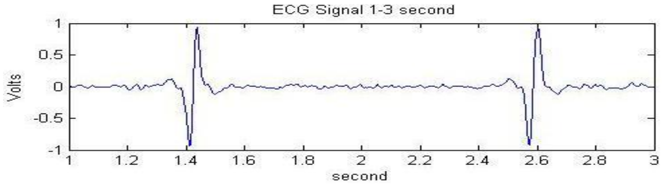

Figure 7 derivative filtering

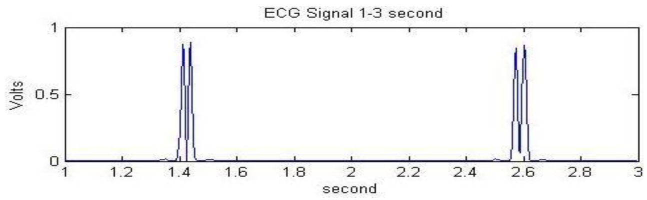

Figure 8 squaring

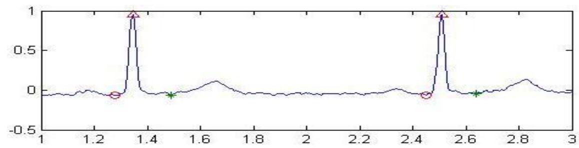

Figure 9 QRS points detection

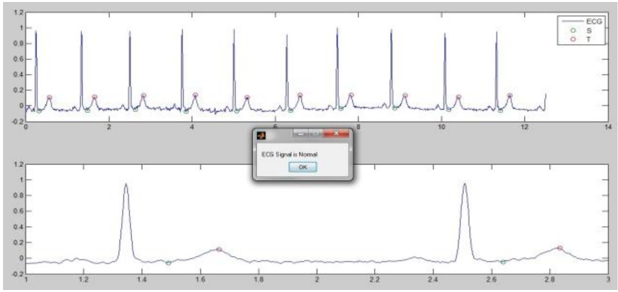

Figure 10 SVM & Validation

Comparison with the other methods:

SVM performs well as compare to the other classification techniques such as extreme learning machine, artificial neural networks etc. in terms of accuracy, gain and sensitivity. The accuracy achieved in extreme learning machine and artificial neural networks nearly equals to 89 % & 87% respectively but it is high in support vector machine [13]. The abnormal & normal condition of the heart patients can be easily checked by using this methodology.

V. CONCLUSION AND FUTURE SCOPE

In this paper, ECG beat classification system using support vector machine have been proposed. Experiments were carried out using the dataset taken from MIT_BIH database. The normal and abnormal condition for the heart patients has been checked successfully fig.10. The results confirm that the ECG classification system using the support vector machine as a classifier increase the sensitivity and accuracy in arrhythmia detection. Wavelet transform & band-pass filter have been used for the de-noising as well as for feature extraction. In future, by using advanced techniques for the classification of ECG signal in combination with the existing classifiers may enhance the accuracy as well as sensitivity in the arrhythmia detection

REFERENCES

[1] T.Fancott, D.H.Wong, " a mini computer system for direct high speed analysis of cardiac arrhythmia in 24 hour ambulatory ECG tape recording", IEEE transaction on Biomed. Engg., 685-693, 1980.

[2]S.S.Anand, S.Yusuf, "stemming the global tsunami of cardiovascular diseases", Lancet 377, 529-532, Feb., 2011.

[3] Amit Kumar Manocha, Mandeep Singh, "An Overview of Ischemia Detection Techniques", Manuscripts of IJSER, France, vol. 2, Issue 11, November 2011.

[4] S.Karpagachelvi, Dr.Arthanari, "*Classification of ECG signal using extreme learning machine*", computer and information science",vol 4,Jan 2011.

[5] C.-K. Siew and G.-B. Huang. (2005), "*Extreme Learning Machine with Randomly Assigned RBF Kernels*", *Int'l J. Information Technology*, vol. 11, no. 1, 2005.

[6]Nalea.Srinivas, A.Vinay, "*ECG signal analysis using data clustering & artificial neural network*", American international journal of research in science and tech., 2328-3491.

[7]F. de Chazal and R. B. Reilly. (2006*). " A patient adapting heart beat classifier using ECG morphology and heartbeat interval features"*, *IEEE Trans. Biomed. Eng.*, vol. 53, no. 12, pp. 2535–2543, Dec. 2006.

[8] R V. Andreao, B. Dorizzi, and J. Boudy. (2006). ECG signal analysis through hidden Markov models, *IEEE Trans. Biomed. Eng.*, vol. 53, no. 8, pp. 1541–1549, Aug. 2006.

[9] Sheng-Wu Xiong, Hong-Bing Liu and Xiao-Xiao Niu. (2005). "Fuzzy support vector machines based on FCM clustering", Proceedings of 2005 International Conference on Machine Learning and Cybernetics, Aug. 2005, vol. 5, pp. 2608- 2613.

[10] V.Rathikarani, P.Dhanalakshmi,(2013), "Automatic classification of ECG signal for heart diseases diagnosis",*IJCSRT*,2321-8827, vol 1.

[11] Prakash D, Uma Mageshwari, Prabakaran (2013), *"Detection of heart diseases by mathematical artificial intelligence algorithm using Phonocardiogram signals", international journal of innovation & applied science*,2028-9324, vol 3, may 2013.

[12] C.A.Bustamante, S.I.Duque, A. Orozco, J.Bustamante (2013), *"ECG delineation and ischemic ST-Segment detection based in wavelet transform and support vector machine*", PAHCE, MEDELLIN COLOMBIA,978-1-4673-6257, April 2013 .

[13] S.Karpagachelvi, M.Sivakumar, *"ECG feature extraction technique-A survey approach"*, IJCSIS, 1947-5500,vol.8,2013.

[14] Available: http://www.physionet.org.

[15] A.Taddel, G.Distante, M.Emlin, "The European ST-T database: standards for evaluating systems for the analysis of ST-T changes on ambulatory electrocardiography", European heart journal, 1164-1172, vol.9, 1992

[16] G.Kokturk, "A *real time simulated QRS detection system constructed using wavelet filtering technique", IEEE*,281-284,1998.

[17]Nahit.Emanet,"ECG beat classification by using Discrete wavelet transform", IEEE,9781-4244-3428, 2009.

[18] F.B,Tuteur, "Wavelet Transformation in signal detection", ICASSP,1435-1438,1988.

[19]Amit Kumar Manocha, Mandeep Singh, "Automatic Delineation of ECG Characteristics Points using Window Search and Multi Resolution Wavelet Transform Approach" Proceeding of 4th International Conference on Emerging Trends in Engineering & Technology, GIMT, Kurukshetra, AEST-03, ACEEE, IDED, USA, 2012, pp755-761.

[20] V.Jakkula, Tutorial on Support vector machine, School of EECS, Washington state university, Pullman 99164.

[21]Guodong Guo and Stan Z.Li. "contents based audio classification and retrieval by support vector machine", IEEE trans. Neural Networks, 209-215, jan,2013

[22]J.C.Burges Christopher, "A tutorial on support vector machine for pattern recognition, data mining and knowledge discovery, 52,121-167, 1998

[23] Nehla Debbabi, Sadok Asmi, "Correction of ECG baseline wander application to the Pan & Tompkins QRS detection algorithm, 978-1-4244-5997, IEEE, 2010.

[24]E.P.L Sornmo, Pablo Lguna, "QRS slopes for detection and characterization of Mycardial Ischemia", IEEE Trans. On Biomed. Engg.,vol.55,468-477, 2008.

[25]Jinho Park, Witold Pedrycz and Moongu Jeon, "*ischemia episode detection in ECG using kernel density estimation, support vector machine and feature extraction",* biomedical engineering online, 2012.