ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 4, Issue 6, June 2015

Improved Time-Frequency Approach For Detection Of Sudden Cardiac Death On Electrocardiogram Signals

Deepthi B, Suresh D S, Roopa S, Rashmi C R

***Abstract*— Sudden cardiac death (SCD) detection on Electrocardiogram (ECG) signal is a popular area of research because of its seriousness of the matter for surviving the life of cardiac patient. Here, an algorithm is proposed for detection and prediction of SCD using ECG signals. It is done by processing the heart rate variability signal through the methods like classical and improved time-frequency methods. The proposed algorithm is mainly evaluated based on the database of patients with sudden cardiac death and healthy person. Here one minute of ECG signal extracted before and few seconds after the cardiac death is considered, then using this extracted one minute signal the heart rate variability(HRV) is computed. Eight features in time domain and four features in frequency domain are extracted by using HRV signal and these features are considered as classical linear features. Then by applying the improved time-frequency method, that is., S-method to HRV signal, statistical features are extracted. Finally extracted features in SM is given to the SVM classifier. The results obtained shows that, improved time-frequency distinguishes the SCD and healthy person effectively compare to other time-frequency methods. The proposed algorithm can be evaluated by using MIT-BIT database. Proposed method gives better resolution and gives 93.30% accuracy.**

***Index Terms*— Electrocardiogram, Heart rate variability, S-Method, Sudden cardiac death, Support vector machine.**

I. Introduction

In the present day scenario, heart disease is the most typical worldwide problem facing by the human beings. Amongst, most of the heart diseases, Sudden Cardiac Death (SCD) is the most breathtaking reaction. SCD detection and prediction on Electrocardiogram (ECG) signal, which is a very special area of research because of the importance of the matter for surviving the life of cardiac arrest patient. In 80% of cases, arrhythmia and coronary disease, which is the first indication that leads to the occurrence of SCD. Remaining 20% 0f cases are due to the structural heart diseases such as hypertrophic cardiomyopathy, dilated cardiomyopathy, arrhythmogenic right-ventricular dysplasia and genetically referred primary arrhythmia syndromes. When these diseases occurred, it leads to the non-appearance arterial pulse and loss of consciousness; whereas sudden death is occurred due to the heart failure which involves continuous failure of heart response and it leads to ambient collapse.

SCD is the condition in which the electrical system to the heart malfunctions, resulting in a disturbance of the heart's normal rhythm and the loss of its ability to deliver blood to the body. This condition leads to the cause cardiovascular mortality in modern systems. Cardiac arrest is the very serious issue, which will dispossess the patient viability within few minutes. When this disease occurs, blood is not pumped to the others parts of the body within few minutes of the occurrence of cardiac event. If he or she get hold of high heart risk, athletics and also even for young person, unexpectedly may SCD occur. When SCD occurs outside of a hospital, there is only chances of 1% - 2% of patients who can carry through it. Ventricular tachyarrhythmia, including ventricular tachycardia (VT), ventricular flutter (VFL), or ventricular fibrillation (VFib) are the diseases which represents arrhythmia are the indication of life inauspicious SCD. For normal person, heart rate is in the range of 60-100 beats per minute. If the heart rate is lesser than this, it is called as brady-cardia; in the same way if the heart rate is higher than this is called as tachycardia. Furthermore, instead of using public access to protect patient from death when they fell down, it is better to take prevention for onset SCD by using medical aid prior to fell down. So that, is it possible to make an early warning, even before crisis presenting half an hour before.

Van Hoogenhuyze, D., Martin, *et al*.[3] observed two HRV measurements, standard deviation of mean of sinus R-R intervals (SDANN) and mean of SD (SD), from 24 hrs HRV. They have evidences to show that HRV is low in patients who experience SCD, and is high in young healthy subjects. Analysis of heart rate variability (HRV) has provided a non invasive method for assessing cardiac autonomic control. L. Murukesan, M. Murugappan, M. Iqbal[2], and Dr. K. Saravanan., gives the machine learning approach on optimal heart rate features for prediction of sudden cardiac arrest. Elias Ebrahimzadeh, Mohammad Pooyan[1], classify SCD person and healthy by comparing classical features of HRV and time-frequency analysis. Smoothed pseudo Wigner distribution is used for time-frequency analysis. And also they used MLP and KNN for better classification. In this article an algorithm was presented for prediction of SCD by using heart rate variability signal. In this algorithm, after preprocessing of ECG signal and HRV extraction, some common features on time domain and frequency domain are extracted. After that, time- frequency transformation is done on the HRV signal.

Manuscript received June, 2015.
***Deepthi B**, Dept., of ECE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur, India.*
***Suresh D S**, Dept., of ECE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur, India.*
***Roopa S**, Dept., of ECE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur.*
***Rashmi C R,** Dept., of CSE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur, India.*

SVM classifier is used to classify the person who is expected to heart death and normal person. **Figure 1** shows flow chart of this algorithm.

II. METHODOLOGY

A. Pre-processing

Considered database of ECG signal consists of 24-hour ECG recording before the heart death and few seconds after the death and also healthy persons. SCD leads to cardiovascular diseases. Patients who is having coronary diseases or having arrhythmia or person who is having signs of previous heart attach are most predictable to SCD. One minute and two minute of ECG recording used respectively.

Figure 2 shows 2 minute just before the occurrence of SCD and few seconds after that ECG signal of a sudden cardiac death patient with 43 years old male patient.

From this figure we can observe that in the signals of a patient before occurring of SCD, there is no major difference between the ECG signal for a person who is exposed to heart death and the ECG signals of healthy persons.

The ECG signal of patient just one minute before the occurrence of the sudden cardiac death was selected as ECG recordings for patients and for healthy persons one minute of the ECG signal was selected randomly. Then, Pan-Tompkins algorithm[8], is applied for extracted one minute ECG signal for removal of noise and to detect QRS-complexes in the signal. RR-intervals and HRV signal is determined from QRS-complexes. Hence, for extracting the features, pre-processed HRV signal is ready.

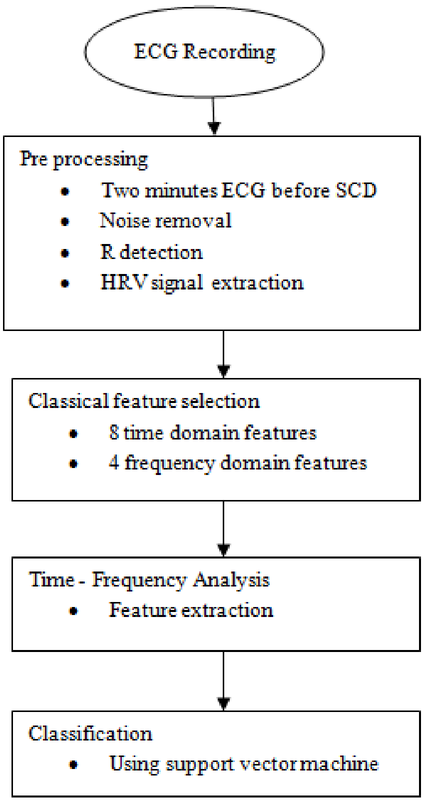

Figure 1: Proposed algorithm flow chart

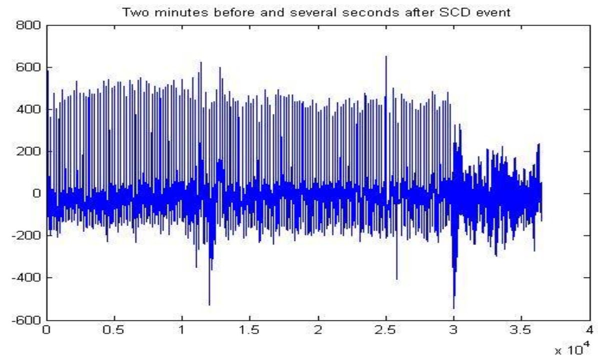

Figure 2: An ECG signal of SCD patient, from 2 minute before SCD event occurrence and several seconds after that.

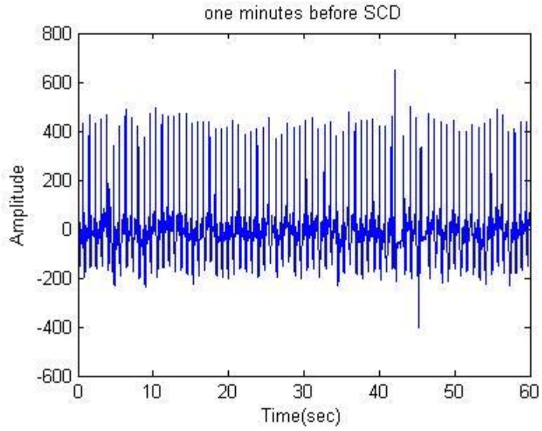

Figure 3(a): One minute ECG signal sample of person with SCD

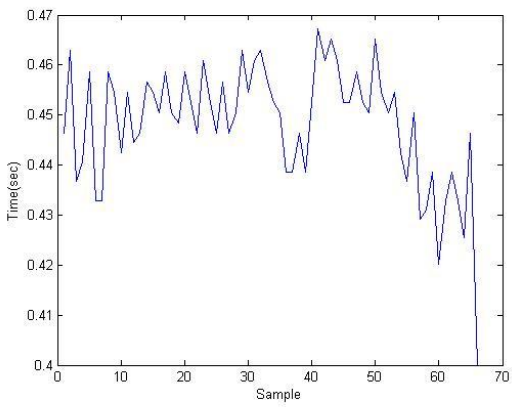

Figure 3(b): Extracted HRV signal from figure 3(a)

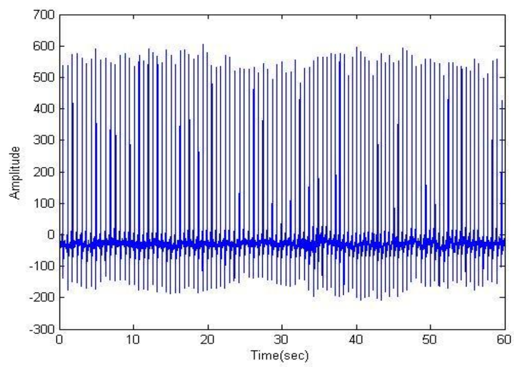

Figure 4(a): One minute ECG signal sample of healthy person

Figures 3 and **4** shows one minute original signal and HRV of both SCD patient and healthy person. Considered healthy person database is with the age of 32 years old male patient.

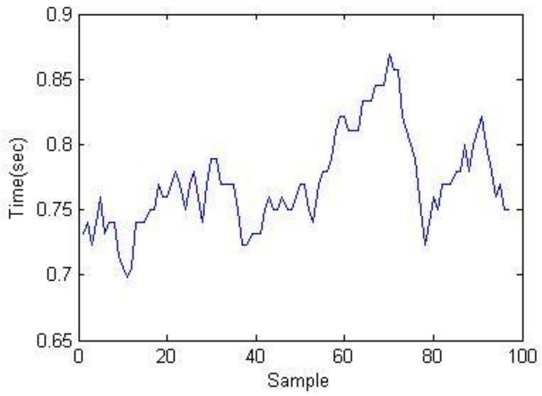

Figure 4(b): Extracted HRV signal from 4(a)

III. CLASSICAL FEATURE SELECTION

In this step time domain and frequency domain linear features are calculated. Features extracted are 8 in time domain and 4 in frequency domain.

A. *Time Domain Features*

It is the analysis of mathematical equations, physical signal or using data with respect to time. For categorising the patient condition, commonly statistical characteristics of the measured physiological signals are used. Statistical time domain features are divided into two types;

- Direct measurement of NN intervals: Here, for the obtained RR-intervals directly the minimum, maximum, mean, median, variance, average power and standard deviations are calculated.
- Measurements from the differences between NN intervals: Here, for mean and standard, difference between the adjacent RR-intervals is to calculated.

i. Direct measurements of NN intervals

1. Minimum of all NN-intervals.

$$\text{Min} = \min(\text{RR(i)}) \quad (1)$$

2. Maximum of all NN-intervals

$$\text{Max} = \max(\text{RR(i)}) \quad (2)$$

3. Mean of all NN-intervals

$$\text{RR}_m = \frac{1}{N}\sum \text{RR(i)} \quad (3)$$

4. Median of all NN-interval

For N is a odd number: $\text{RR}_{med} = \frac{N+1}{2}$ (4)

For N is a even number:

$$\text{RR}_{med} = \left(\left(\frac{N}{2}\right) + \left(\frac{N}{2}+1\right)\right)/2 \quad (5)$$

5. Standard deviation of all NN-interval

$$\text{SDNN} = \sqrt{\frac{1}{N}\sum(\text{RR(i)} - \text{RR}_m)^2} \quad (6)$$

ii. Measurements from the differences between NN intervals

1. Root mean square of the sum of the squares of differences between adjacent NN Intervals (RMSSD)

$$\text{RMSSD} = \sqrt{\frac{1}{N}\sum(\text{RR(i+1)} - \text{RR(i)})^2} \quad (7)$$

2. Difference between the adjacent NN Intervals of Standard deviation (SDSD).

$$\text{SDSD} = \sqrt{\frac{1}{N}\sum(\text{RR}_{(diff)} - \overline{\text{RR}_{(diff)}})^2} \quad (8)$$

$$\text{RR}_{(diff)} = (\text{RR(i+1)} - \text{RR(i)}) \quad (9)$$

$$\overline{\text{RR}_{(diff)}} = \frac{1}{N}\sum(\text{RR(i+1)} - \text{RR(i)}) \quad (10)$$

3. The proportion derived by dividing the number of interval differences of NN-intervals greater than 50ms by total number of NN-intervals (PRR50):

$$[(\text{RR(i+1)} - \text{RR(i)})] > 50\text{ms}/[\text{total}(\text{RR(diff)})] \quad (11)$$

B. *Frequency Domain Feature*

Power spectral density of the RR-interval series are calculated in frequency domain analysis. A package of frequency domain features are also extracted with the set of time domain features for raw signal of both SCD patient and a healthy person. After all, the time domain features are effective in calculation but they lack in individualizing between sympathetic and parasympathetic contents of the RR-intervals.

The Respiratory Sinus Arrhythmia (RSA), is the most noticeable periodic element of HRV, which is generally considered in the high frequency range of 0.15 - 0.4Hz. This high frequency component of HRV represents parasympathetic activity. Another important element of the HRV signal is low frequency, which is in the range of 0.04 - 0.15Hz. The heart rhythms with LF range is referred as sympathetic activity, which is due to regulating blood pressure and it is related to baroreceptor control and this range is also referred as parasympathetic activity. Frequency range less than 0.04Hz are considered to as very low frequency and ultra low frequency. At these frequency range fluctuations in the RR-intervals are obtained and these fluctuations are due to thermoregulation mechanism. In this work, considered frequency domain features of RR-intervals are power spectral bands such as VLF, LF, HF and LF/HF.

The power spectral density (PSD) which is shown in **Figure 5** is calculated by using Lomb-Scargle method. It is a frequency analysis tool, which equivalents the unbalance spaced data to least-square fitting of sinusoidal waves. **Figure 6** shows the spatial distribution of mean and standard deviation of SCD and healthy person. From this, we can easily discriminate the features between normal and healthy person.

IV. TIME-FREQUENCY DOMAIN ANALYSIS

A method to analyze non stationary HRV signal, is Time-Frequency(TF). Signals are commonly analyzed in either the time or frequency domain. However, some signals exhibit significant time variations of the frequency content. For these cases time-frequency representations can be used, since they combine time and frequency domain analyses to yield a more revealing picture of the temporal localization of signals spectral components.

TF analysis can be divided into three categories;

ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 4, Issue 6, June 2015

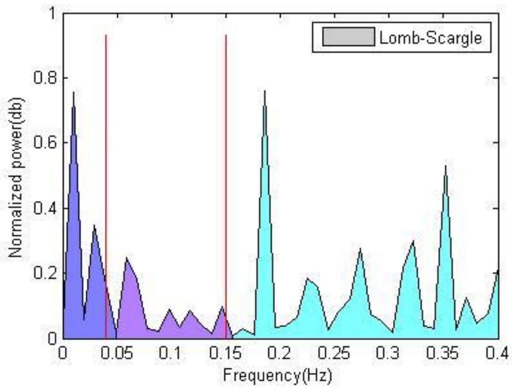

Figure 5: PSD of HRV signal extracted from 4(b); power in each frequency bands are indicated.

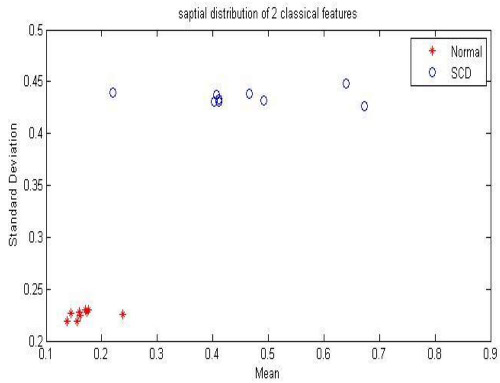

Figure 6: Spatial distribution of mean and standard deviation of SCD and healthy person

non-parametric linear TF method, which includes short time Fourier transform and wavelet transform [4],[5], nonparametric quadratic TF methods, which includes Wigner Ville distributions[6], and its improved versions and lastly, parametric time-varying methods includes autoregressive models[7]. By using all these methods for analysis of signals so many drawbacks are induced at the output that is., less accuracy trade-off between time and frequency resolution, and occurrence of cross terms for multi-component signal. In this paper S-method(SM) is preferred to overcome all those drawbacks and give to give the better response with high resolution and reduction in cross-terms by suppressing the auto-terms. The main drawback of SM is very sensitive to noise.

A. S - Method

S-method is derived with the aim of having same auto-terms concentration as in Wigner Ville distributions in the absence of cross-terms. S-method is mainly based on STFT[9], [10]. S-method is simple in realization and it has applications in the field of speech signal analysis, radar signals etc,.

Basically, the direct relationship between STFT and pseudo Wigner distribution gives S-method. S-method is the distribution between spectrogram and Wigner Ville distribution and which combines good properties, that is, the reduce of cross-terms and high resolution signals. Combining the STFT values along with frequency analysis gives better time-frequency representation. The SM discrete signal is defined by

$$SM(t,\omega)=\int_{-\infty}^{+\infty} P(\theta)STFT(t,\omega+\theta)STFT^{*}(t,\omega-\theta)\,d\theta \quad (12)$$

Where n and k are the discrete time domain and frequency domain variables respectively, P(l) is the window function of the length 2L+1. In special cases, for L= 0 and L= N/2, spectrogram and WVD are obtained. Hence, the quality of spectrogram towards the quality of the Wigner distribution is improved by the terms in the summation.

$$SM(n,k)=|STFT(n,k)|^{2}+2Re\{\sum_{l=1}^{L} STFT(n,k+l)STFT^{*}(n,k-l)\} \quad (13)$$

To enable the complete summation over the auto-terms the window P(l) used must be wide enough. For removal of cross terms in the signal, distance should be narrower than the minimal distance between the auto-terms.

i. Time-Frequency Feature Extraction

For extracted HRV signal, after time-frequency analysis, statistical parameters are calculated. These statistical parameters are considered as time-frequency features. The features are;

- min_RR: minimum of all RR-interval
- max_RR: maximum of all RR-intervals
- men_RR: mean of all RR-intervals, represents average of all value
- med_RR: median of all RR-intervals
- std_RR: standard deviation of all RR-intervals
- vr_RR: variance of all RR-intervals

V. MACHINE LEARNING APPROACH

Support Vector Machine[11] is employed for classification of healthy person and SCD patient from one minute of ECG signal. The mentioned features extracted in time-frequency domain of one minute ECE signal just before the occurrence of SCD, are extracted and compared with the same features of healthy person through SVM classifier.

SVM is the machine learning approach which is widely used in the pattern recognition and data analysing. Compare to other machine learning approach, SVM is very strong method and it reduces the use of external parameter tuning for better classification. SVM is based on computational learning theory for minimization of structural risk.

SVM, based on the input features, finds hyper-planes that best separate the classes with maximum distance between hyper-planes as shown in **Figure 7**. But, generally for low dimensionality feature vectors, always poor class of separation will be resulted. Still, in SVM, for improving class separation performance for input, different kernel functions

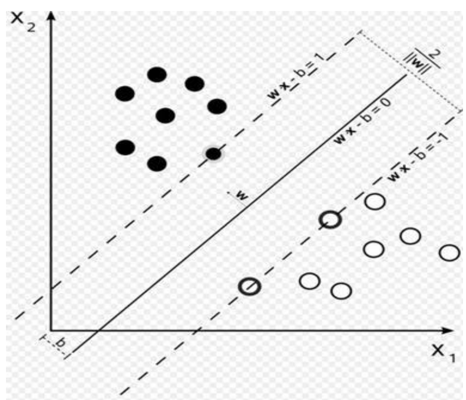

Figure 7: Hyper-plane

are used. The epochs in the data set were randomly divided into two sets: a Training Set and a Testing Set. 70% of the epochs are used to train of SVM while 30% were used to test the performance of the classifier. This process is done to check the accuracy.

VI. RESULTS

The performance of the processed method is evaluated with one minute of ECG signal just before the occurrence of SCD. By using SVM classifier, predicted accuracy is 93.30%. **Table 1** shows that, by using s-method we can get efficient output than other time-frequency method[1]. In classifier, for training set 20 datasets are considered that is 10 from normal sinus rhythm and 10 from SCD patient and 15 datasets are considered in testing set. The result of classification in SVM is by means of Time-frequency analysis for one minute of ECG signal just before the occurrence of SCD. Wang et al. [12] used 2-minute (just before SCD) of the same dataset to predict SCD.

Table 1: The results of classification by means of SVM classifier, via TF methods

Classification Rate of One minute ECG signal

Time-Frequency methods	SVM Classifier
WVD	86.61%
S-method	93.30%

The results of our proposed system illustrates that electrocardiogram signals of the SCD patients features when compared with healthy persons feature, there is a explicit difference between each features. Although these differences could not be detected by means of simple methods, but the time-frequency (TF) method has far more ability to detect these differences. These results show that by TF method one can predict the sudden cardiac death, even 2 minutes before SCD occurrence.

VII. CONCLUSION

In this work, we had proposed an algorithm for SCD detection using features derived from HRV signals in time, frequency and time-frequency domains. S-method provides a efficient tool for time-frequency analysis with time instance. S-method is used to identify the optimal features for SCD detection using SVM classifier. With the combination of S-method and SVM classifier, gives efficient accuracy in classifying the difference between SCD patient and healthy person.

REFERENCES

[1] Elias Ebrahimzadeh, Mohammad Pooyan, "Early detection of sudden cardiac death by using classical linear techniques and time-frequency methods on electrocardiogram signals", J. Biomedical Science and Engineering, 2011, 4, 699-706.

[2] L. Murukesan, M. Murugappan, M. Iqbal, and Dr. K. Saravanan, "Machine Learning Approach for Sudden Cardiac Arrest Prediction Based on Optimal Heart Rate Variability Features", Journal of Medical Imaging and Health Informatics Vol. 4, 1–12, 2014.

[3] Van Hoogenhuyze, D., Martin, G., *et al*., (1998) Spectrum of heart rate variability. *Proceedings of Computers in Cardiology*, Chigaco, 13-16 September 1998, 65.

[4] Keselbrener, L. and Akselrod, S. (1996) Selective discrete Fourier transform algorithm for time-frequency analysis: method and application on simulated and cardiovascular signals. *IEEE Transactions on Biomedical Engineering*, **43**, 789-802.

[5] Clari, F. Vallverdd, M., Baranowski, R., Chonowska, L., Martinez, P. and Caminal, P. (2000) "Time-frequency representation of the HRV: A tool to characterize sudden cardiac death in hypertrophy cardiomyopathy patients". *Proceedings of the* 22*nd Annual International Confer-ence of the IEEE*, **1**, 71-73.

[6] Pola, S., Macerata, A., Emdin, M. and Marchesi, C. (1996) "Estimation of the power spectral density in non-stationary cardiovascular time series: Assessing the role of the time-frequency representations (TFR)". *IEEE Transactions on Biomedical Engineering*, **43**, 46-59.

[7] Martin, W. and Flandrin, P. (1985) Wigner-Ville spectral analysis of non-stationary processes. *IEEE Transactions on Acoustics*, *Speech and Signal Processing*,

[8] Jiapu Pan and Willis J. Tomkins, senior member, IEEE, "A Real-Time QRS Detection", IEEE transactions on Biomedical Engineering, vol. BME-32, No.3, 1985.

[9] Haina Rong, Gexiang Zhang, Weidong Jin,(2007), "an improved time frequency analysis method for noisy multi-component signals", IEEE International Conference on Signal Processing and Communications (ICSPC 2007), 24-27 November 2007, Dubai, United Arab Emirates.

[10] T. Thayaparan, L.J. Stankovic and M. Dakovic, "A novel approach for the detection of maneuvering air targets in sea-clutter using High-Frequency Surface-Wave radar"

[11] S. S. Mehta, and N. S. Lingayat, *Member, IAENG, "*Support Vector Machine for Cardiac Beat Detection in Single Lead Electrocardiogram*", IAENG International Journal of Applied Mathematics, 36:2, IJAM_36_2_4.*

[12] Shen, T.W., Shen, H.P, Lin, C. and Ou, Y. (2007) Detection and prediction of Sudden Cardiac Death (SCD) for personal healthcare. 29*th Annual International Conference of the IEEE*, Buenos Aires, 22-26 August 2007, 2575-2578.

Deepthi B pursuing M.Tech., Dept., of ECE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur.

Suresh D S received BE in IT branch, MBA, M.Tech and PhD. His area of research is in the field of Embedded systems. Currently, he is a Director of Channabasaveshwara Institute of Technology. He authored a few Text books and has published papers in many national/international journals & Conferences. He has guided many projects sponsored by KSCST and has recently filed patent of his project on "Health Monitoring System".

Roopa S received BE in ECE and M.Tech in Digital communication. Currently pursuing Ph.D in Adaptive signal processing under VTU. Currently working as Asst.Professor, Dept., of ECE, Channabasaveshwara Institute of Technology, Gubbi, Tumkur.

Rashmi C R received BE and M.Tech in CSE branch. Currently working as Asst.Professor, Dept., of CSE, Channabasaveshwara Institute of Technology.