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Combining parameters for detection of ventricular fibrillation

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Abstract: *The irregularity in human heart beat indicate the disorders associated with it.Identifying the cause of arrhythmias is important in its treatment.The method of correcting shockable arrhythmias using Automatic External Defibrillators(AED) are of great demand in these days .The detection of arrhythmias and defibrillating the irregularity within minimum time fromthe ventricular fibrillation can considerably minimizes the death rate.Instances were reported in which the external defibrillator failed to act on time or interrupted the non-shockable rhythm as shockable. Research in this area is necessary to develop an effective algorithm that reduces this misrepresentation.The error rate can be minimised by combining various ECG parameters. It is preferable to use right combination of minimum number of parameters to minimise computation time and error rate. This paper uses ten ECG parameters in a combined manner for differentiating ventricular fibrillation and non ventricular fibrillation using Gaussian Support vector machine classifier.This project is simulated using MATLAB. On simulation the Balanced Error Rate is found to be around 7.5 percentage*.

Keywords- Defibrillation,Support vector machine, ECG parameters.

I. INTRODUCTION

Cardiac arrest is a major cause of higher death rate in present day.Initiation of timely treatment is important in life saving. Reason for cardiac arrest determine the type of treatment technique.Defibrillation is a technique for treatment of shockable arrhythmias. Ventricular fibrillation is a class of shockable rhythm which can be effectively treated using defibrillation . It is done by applying electric shock either invasively or noninvasively to heart. Non invasive defibrillators are considered as faster first aid treatment procedure to restore the normal heart rate. The vital component in defibrillator is detection algorithm. Diverse detection algorithms are there that takes into consideration of either time domain, frequency domain ,complexity , shape features of ECG signals. These parameters are used in classification of different scenarios of VF ,nonVF,ventricular tachycardia ,shockable and nonshockableECG signals.When individual parameter based algorithm is implemented in real time, its performance decrease from the investigated values. Combination of different ECG parameters in detection technique can improve the efficiency[1]. The next vital component in defibrillator is classifier. Classifiers like neural network,support vector machine, KNN classifier etc can be used in classification. The premier work in this field was first introduced by Nitish V Thakor, which uses width,height and area of beat[2] in analysing the arrhythmia.This techniques main drawback is the overload of data collection and time consuming analysis. Later Thakor introduced new temporal based algorithm called TCI[3] and sequential hypothesis was used in classification. This algorithm operates on binary

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signal and hence easier than previous work.A spectral domain algorithm was proposed by Kuo called VFleak[4] algorithm,which involve a narrow band rejection filtering in mean frequency of ECG.Another spectral algorithm(SPEC)[5] measures the amount of energy contained in different set of frequency ranges. Y. S. Zhu and Thakor introduced complexity based algorithm(CPLX)[6]that is based on repetitive patterns .Amann proposed two complexity based algorithms, first one uses Hilbert transform called Hilbert transform algorithm(HILB) [7]which has best sensitivity for a given specified specificity,second one is time-delay reconstruction (PSR) [8],at a given specificity it has greater IROC .Both this algorithms identify random behaviour.The main drawbacks of both is that its doesn't take in to consideration of shape of ECG signal which bear information.H.Li put forward Sample entropy algorithm[9],which uses entropy values.

This is useful in analysing short and noisy ECG.Modified and efficient temporal parameter than previously defined TCI named threshold crossing sample count were proposed by M.A Arafat (TCSC)[10]which involve comparison with threshold and counting its crossings. In real time,algorithms exhibits advantages and disadvantages. An efficient algorithm must work effectively in real time and can be easily implementable . The shock should not be given to a person with nonshockable arrhythmias.Faster, accurate and efficient algorithm is required in Automatic external defibrillators. Combining parameters with improved efficiency and less computation time is an effective approach for decreasing the error rate.This paper involve joining such features and improving performance.

II. DATABASE

The database of ECG signal are from the the CUDB[11] which are available at the PhysioNet repository. The files contain 8-minute long recordings of VF,normal sinus, flutter etc.The signals are sampled at 250 HZ.Using the annotation provided in recordings,10-second long each type of ECG signal are taken in .mat format. The description about the records including the sampling frequency,nature of irregularity ,age of patient are listed in database .The ECG signals are recorded in time/data format .

III. PREPROCESSING

The ECG is recorded using electrode placed on surface of human body. The signals are of millivolts range. The recording technique is highly sensitive to noise and other artifacts. The irregularity can be due to misplacement of electrodes,muscle movement, non cardiac noises, powerline interference of about 60 Hz from other electromagnetic devices. The noises and other artifacts are removed by four preprocessing methods[1].

1) Mean subtraction Subtracting mean value from the signal
2) Moving average filter A moving averaging Filter to eliminate 60 HZ powerline interference
3) High pass filter Baseline drift is minimised using high pass filter of cut off frequency 1 HZ
4) Low pass filtering To reduce muscle noise above 30 HZ second order butterworth low pass filter is used.

IV. ECG PARAMETERS

The preprocessed signal is analysed for duration of 8 -sec

1) Wavelet based algorithm:[12] To find the maximum of absolute values of hyperbola located in wavelet space,wavelet transform followed by fourier transform is defibrillation process.

2) Hurst index :[13] The detailed coefficients of wavelet decomposition of ECG signal up to 4 levels are calculated. From this the Hurst index is calculated by equation:

$$\log 2\ (\text{variance}(\ j\text{thdetailedcoefficients})) = (2H+1)\ j \qquad (1)$$

3) Threshold crossing interval:[3] Average intervals between threshold crossings are investigated.

$$N = \frac{Number\ of\ samples\ that\ crossV_0}{Total\ number\ of\ samples} \times 100 \qquad (2)$$

$$N = \frac{1}{L_e - 2} \times \sum_{i=1}^{L_e-2} N_i \qquad (3)$$

4) Standard Exponential:the ratio[12] between decreasing exponential placed in maximum amplitude with ECG.Decreasing function is given by

$$E_s(t) = M \times exp(\frac{(-|t-t_m|)}{\tau} \qquad (4)$$

5) Threshold crossing sample count:[10] Number of samples that cross the threshold values.On an Le duration episode ,TCSC value is evaluated for average Le-2 values.

$$TCI = \frac{1000}{(N-1) + \frac{t_2}{t_1+t_2} + \frac{t_3}{t_3+t_4}} \qquad (5)$$

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6) Modified Exponential:An improved form of STE, called MEA [12],Identifying crossing points by placing ECG at relative maximum. Exponential function is given by equation

$$E_i(t) = \begin{cases} A_i \times exp^{\frac{-|t-t_{m,i}|}{\tau}} & t_{m,i} \leq t \leq t_{i,j} \\ \text{given ECG signal} & t_{c,i} \leq t \leq t_{m,i+1} \end{cases} \quad (6)$$

7) Mean absolute value:[?]averaging 2-sec Le □1 consecutive values.

$$MAV = \frac{1}{N} \times \sum_{n=0}^{N-1} |x(n)| \quad (7)$$

8) VF filter:[4]finds frequency with maximum amplitude,if it in frequency range of ventricular fibrillation then VF parameter is calculated. Period is given by the equation

$$T = \frac{1}{f_p} \times f_{sample} \quad (8)$$

where fp is the frequency correspond to maximum amplitude 3-second ECG and fsamp is the sample frequency (250Hz).Parameter is calculated using through the correlation technique and is given by equation

$$VF = \frac{\sum_{j=T/2}^{N-1} |x_j + x_{j-T/2}|}{\sum_{j=T/2}^{N-1} |x_j| + |x_{j-T/2}|} \quad (9)$$

where x j is the jth signal sample; T is the period calculated in equation [8] and N is number of samples in 2-sec ECG.

9) Median frequency(FM):[14]Duration of cardiac is calculated using this parameter. This will determine if the defibrillation process will be successful.

$$FM = \frac{\sum_{i=1}^{n} (f_i . p_i)}{\sum_{i=1}^{n} p_i} \quad (10)$$

10) Spectral Algorithm:[12] using Fourier analysis the energy contained in different frequency bands are estimated.

V. SVM CLASSIFIER

SVM is an efficient classification technique which creates a optimal separating hyperplane with maximum margin.The ECG parameters calculated are nonlinear in nature. So Gaussian SVM is used for classification. All the features estimated are used for training the Support Vector Machine classifier. In nonlinear data SVM map the two classes using kernel method[15],here gaussian kernal is used and form discriminant function that minimizes the cost function

$$\min_{V,a_i,\xi_i} \frac{1}{2} \times \| X \|^2 + R \sum_{i=1}^{M} \xi_i \quad (11)$$

$$\text{subject to} \quad y_i(\langle \phi(v_i), x \rangle) + a) - 1 + \xi_i \geq 0 \quad (12)$$

$$\xi_i \geq 0, i = 1...M \quad (13)$$

where f(vi) is maps the nonlinear data to a higher dimensional space , xi represent the slack variable and R determine the shape of discrimination function and is the regularization parameter.As the parameters are nonlinear Gaussian type SVM is used for classification.

VI. PERFORMANCE EVALUATION

The performance of the detection algorithm is evaluated using Sensitivity(SE):the proportion of correctly identified VF,Specificity(SP):[1] the proportion of correctly identified nonVF.

$$SE = \frac{TruePositive}{TruePositive + FalseNegative} \quad (14)$$

$$SP = \frac{TrueNegative}{TrueNegative + FalsePositive} \quad (15)$$

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True positive(TP) indicate the number of signals correctly classified as VF,True negative(TN) is number of signals correctly detected as NVF,False positive(FP) is number of NVF classified as VF and False negative (FN) is number of VF classified as NVF. The efficiency of classifier is estimated by Balanced Error Rate(BER) ,positive predictivity (PP)and accuracy(AC).

$$BER = \frac{1}{2} \times \left(\frac{FN}{PC} + \frac{FP}{NC}\right) \quad (16)$$

$$PP = \frac{TP}{TP+FP} \quad (17)$$

$$ACC = \frac{TN+TP}{PC+NC} \quad (18)$$

where where PC = TP + FN and NC = TN + FP.As indicated in previous paper [1] as the number of parameters increases the BER decreases.The 10 parameters are calculated for VF and non VF ECG signals The SVM is trained using these parameters.

TABLE I
TESTED SAMPLE OUTPUTS

Tested sample	Number
NonVF	33
VF	33
TP	30
FP	2
TN	31
FN	3

On testing samples and evaluating the performance is given by

TABLE II
PERFORMANCE EVALUATION

Parameter	Value (in percentage)
SE	90.9
SP	94
ACC	92.42
PP	93.75
BER	7.5

On comparing with previous studies stated in [1] which uses 13 set of ECG parameters,the BER is always above 8. It also stated that the BER can be decreased by increasing the number of ECG parameters.This paper aims at combining 10 parameters and there by reducing BER. On evaluation, the BER is found to be around 7.5 which is less compared to the BER in[1] and by using lesser number of parameters. The accuracy has improved even without the use of feature selection in classifier. Meanwhile sensitivity and Specificity decreased than in [1].

VII. CONCLUSION

The detection algorithm using combination of 10 parameters leads to better BER and accuracy than previous studies which uses 13 parameters.The Specificity and sensitivity parameter needs to be further improved for real time application . This can be done by using complexity parameter along with temporal, spectral and wavelet based parameters.Avoiding those parameters that have less detection performance and combining those of high performance can improve performance and computation time.

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