

Feature Extraction for Detection of Ventricular Tachycardia and Ventricular Fibrillation using WAVELET Decomposition

Anmole Sinha
Senior Undergraduate(ECE)
Shri Mata Vaishno Devi
University, Katra, J&K

Gaurav Singh
Senior Undergraduate
Shri Mata Vaishno Devi
University, Katra, J&K

Monika Kashyap
Senior Undergraduate
Shri Mata Vaishno Devi
University, Katra, J&K

ABSTRACT

Proper rhythm of the heart of a human is of utmost importance for his survival so that there is proper oxygen supply throughout the body for proper functioning of all body parts. However, Ventricular Tachycardia(VT) and Ventricular Fibrillation(VF) are irregular cardiac rhythms that are life threatening and hence their accurate detection is very necessary. In this paper, feature extraction technique has been presented based on wavelet decomposition from the Electrocardiogram (ECG) in an attempt to differentiate between VT and VF. A set of Discrete Wavelet Transform (DWT) coefficients, which contain maximum information about the arrhythmias, is selected from the wavelet decomposition. Daubechies 6 wavelet has been used in the decomposition process. SVM (Support Vector Machine) and knn classifiers has been deployed for classification of the two rhythms and compared the result of the classifiers. The ECG signals for training the classifier and testing purpose is taken from MIT malignant ventricular arrhythmia database. The sensitivity of the SVM and knn classifier were found to be 91.82% and 92.38% respectively.

General Terms

Feature extraction; Ventricular Tachycardia; Ventricular Fibrillation

Keywords

Daubechies 6 Wavelet; ECG; Ventricular Tachycardia; Ventricular Fibrillation; Wavelet Decomposition, Discrete Wavelet Transform (DWT)

1. LITERATURE REVIEW

Ventricular tachycardia (VT) and ventricular fibrillation (VF) are the arrhythmic events in the majority of patients who report sudden cardiac death. Sustained ventricular tachycardia leads to ventricular fibrillation in which the lower chambers of the heart beat in a chaotic fashion.

Research is being conducted since years to try to understand the processes occurring during such events so as to develop methodologies to reduce their threat to human life. Felipe Alonso-Atienza, Eduardo Morgado, Lorena Fernandez Martinez, Arcadi Garcia-Alberola, Jose Luis Rojo-Alvarez used Threshold Crossing Interval (TCI), Threshold

Crossing Sample Count (TCSC), Standard Exponential (STE), Modified Exponential (MEA), Mean Absolute Value (MAV), Complexity Measurement (CM), Hilbert Transform (HILB), Sample Entropy (SpEn) for detection of life threatening arrhythmias[1]. Mohd. Afzan Othman, Norlaili Mat Safri, Ismawati Abdul Ghani, Fauzan Khairi Che Harun, Ismail

Ariffin proposed mean value calculation for detection of VT and VF[2]. Felipe Alonso-Atienza, Jose Luis Rojo-Alvarez, Alfredo Rosado-Munoz, Juan J. Vinagre, Arcadi Garcia-Alberola, Gustavo Camps-Valls used spectral and temporal parameters[3]. Zhen-Xing Zhang, Sang-Hong Lee, Hyoungh J. Jang, Joon S. Lim have used fuzzy neural network(FNN) for classification[5] and many more have worked on different set of parameters using different classifiers to design an accurate classification system to differentiate between VT and VF.

This paper presents an attempt to differentiate between VT and VF using wavelet features.

2. INTRODUCTION

Arrhythmia is a term which states that the regular rhythm of heart is disturbed. Among various types of arrhythmias, ventricular arrhythmias such as ventricular tachycardia (VT) and ventricular fibrillation (VFIB) are life threatening. Hence, it is very important to detect features that can be used to differentiate between the two for reliable design of an arrhythmia detecting system. The detection of this cardiac arrhythmia is difficult because the waveform of these life threatening arrhythmias changes with time. If the system is not able to detect the arrhythmia accurately or there is a false positive detection and we initiate a defibrillator to give unnecessary treatment—in both the situations the patient's life is at risk.

Discrete Wavelet Transform(DWT) has been used for decomposing the ECG signals and analyzing the signals that lie in the frequency range that contains maximum information. Ventricular fibrillation is characterized by continuous bands in the range of 2-10 Hz; ventricular tachycardia is characterized by two distinct bands: the first band in the range of 2-5 Hz and the second in the range of 6-8 Hz[10]. So, we have decomposed the signals into 6 levels using Daubechies 6 wavelet and extracted features from the fourth, fifth and sixth levels of decomposition that could differentiate between Ventricular Tachycardia (VT) and Ventricular Fibrillation (VF) as these levels contain maximum information about them. We have taken ventricular arrhythmia episodes taken from MIT-BIH malignant ventricular arrhythmia databases.

3. LIFE THREATENING ARRHYTHMIAS

The heart contracts and relaxes in an ordered manner. The impulse that signals the heart to contract is given to the sinus node. First the upper chambers contract and then the lower chamber contracts when the pulse reaches. However, there may occur certain conditions due to which the contraction and

relaxation of the heart may not be as expected. If the sinus node sends the impulses too fast or too slow then the heart beats too fast or too slow. Heart block occurs when these electrical impulses are not transferred correctly and various chambers contract in an uncoordinated manner. At this time the normal pumping of the blood is disrupted. Any disturbance of the normal sinus rhythm is called arrhythmia. Ventricular tachycardia and ventricular fibrillation are serious arrhythmias which leads to sudden death if it is not detected in appropriate time and is therefore said to be life threatening.

3.1 Ventricular Tachycardia(VT)

It is the state of rapid heartbeat that arises from improper electrical activity of either of the ventricles of the heart which are responsible for pumping blood. Under such state the heart does not have enough time to fill blood and is a potentially life-threatening arrhythmia because it may lead to ventricular fibrillation and sudden death.

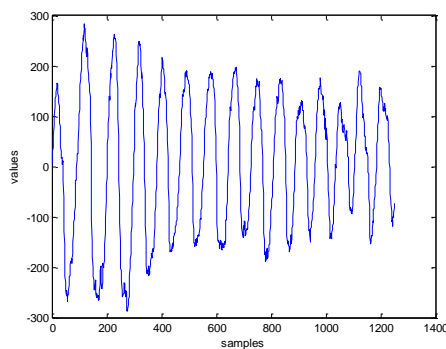


Fig 1. ECG with the defect of Ventricular tachycardia(signal 605 from database)

3.2 Ventricular Fibrillation (VF)

In this case, the beats arise from many different locations of the ventricles each trying to signal the heart to beat. It is a condition in which there is uncoordinated contraction of the cardiac muscle of the ventricles in the heart, making them quiver rather than contract properly. As a result, the heart beat increases, ventricle/s begin to send chaotic electrical stimuli resulting in random ventricular depolarization and becomes life threatening due to poor supply of oxygen to the body parts including the brain.

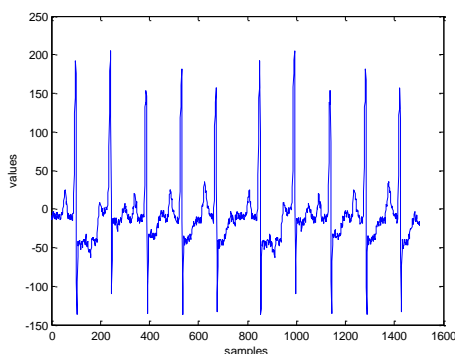


Fig 2. ECG with the defect of Ventricular Fibrillation(signal 422 from database)

4. WAVELET DECOMPOSITION

It is a mathematical tool through which information can be extracted from a signal both in time and frequency domain.

4.1 Discrete Wavelet Decomposition(DWT)

A discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled through which the ECG signals are decomposed at various scales into its time-frequency components. In this method, two filters, a low pass filter and a high pass filter are used for the decomposition of ECG at different scales. Each filtered signal is down sampled to reduce the length of the component signals by a factor of two. The output coefficients of low pass filters are called the approximation coefficients while the output coefficients of high pass filters are called the detail coefficients. The approximation signal can be sent again to the low pass and high pass filters of the next level for second level of decomposition and so on up to the required decomposition level.

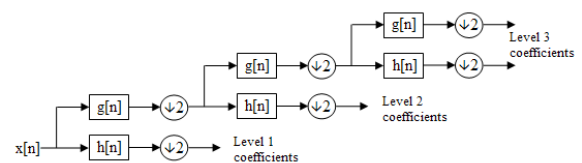


Fig3. Three level wavelet decomposition

From the above diagram, it is clear that as the signal is passed through the filter, it is separated into two components low pass and high pass. The low pass component is the scaling or smoothing function (approximation) S_nk , and the high pass component is the detail signal D_nk [11].

5. METHODOLOGY

5.1 Database

For the study and experimentation MIT-BIH Malignant Ventricular Ectype Database (MIT-BIH vfdb) has been used. All the signals were sampled at a frequency of 250Hz.

5.2 Preprocessing

Baseline noise removal and normalization on the signals has been deployed before feature extraction.

5.3 VT and VF detection method

Ventricular fibrillation is characterized by continuous bands in the range of 2-10 Hz; ventricular tachycardia is characterized by two distinct bands: the first band in the range of 2-5 Hz and the second in the range of 6-8 Hz[1]. So, after the decomposition of the pre-processed signals into 6 levels using Daubechies 6 wavelet and extracted features from the fourth, fifth and sixth levels of decomposition that could differentiate between Ventricular Tachycardia (VT) and Ventricular Fibrillation (VF) as these levels contain maximum information about them. It is found that the normalized energy of the fourth($Ed(4)$), fifth($Ed(5)$), sixth($Ed(6)$) levels and the normalized apparent energy of the fifth level($Appe(5)$) were different for VT and VF episodes. Hence, these were the parameters selected for discriminating between the two arrhythmias.

Figure1 and 2 show original VT and VF episodes of 5s duration. After baseline noise removal and normalization, various parameters for both have been extracted which have values different from each other as can be seen in figures 4 and 5.

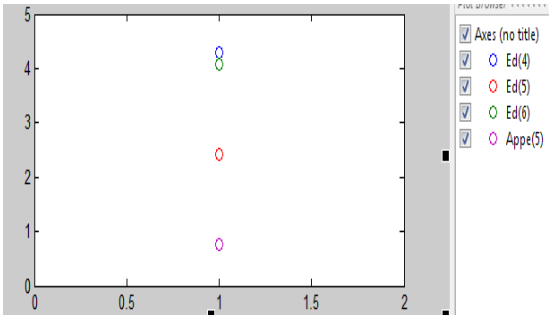


Fig 4. Values of various features extracted from VF episode from signal 422

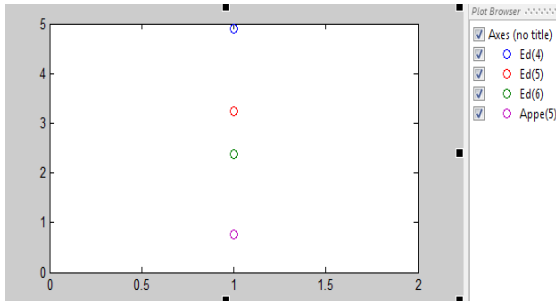


Fig 5. Values of various features extracted from VT episode from signal 605

All the simulation has been done on MATLAB.

The extracted features for all the signals used for training the classifiers for detection of VT and VF have values such that they can be differentiated by the classifier.

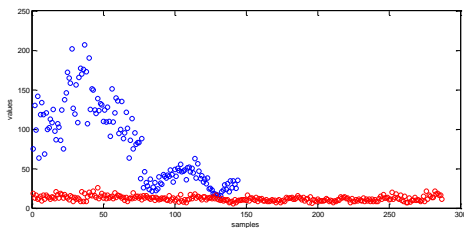


Fig 6. Classification of VT(blue) and BF(red) based on normalized energy of 4th level of decomposition

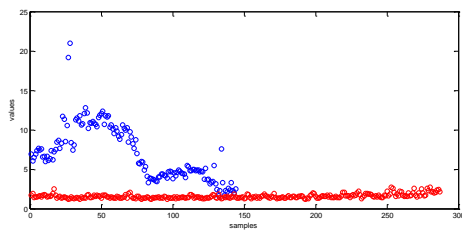


Fig 7. Classification of VT(blue) and BF(red) based on normalized energy of 5th level of decomposition

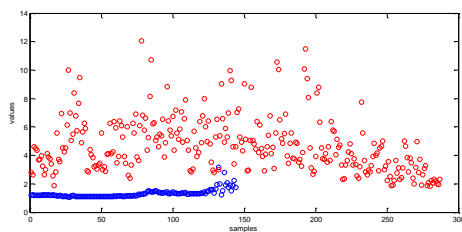


Fig 8. Classification of VT(blue) and BF(red) based on normalized energy of 6th level of decomposition

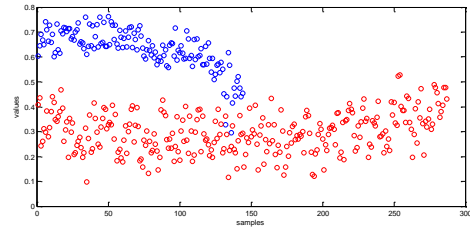


Fig 9. Classification of VT(blue) and BF(red) based on normalized apparent energy of 6th level of decomposition

6. EXPERIMENTAL RESULT AND CONCLUSION

The classifier training and testing has been done using the ECG signals from the MIT-BIH malignant ventricular arrhythmia database. The ability of each classifier to differentiate between the two life threatening arrhythmias has been tested based on the above four parameters using the sensitivity parameter (i.e., the measure of sensitiveness of the classifier for the two arrhythmias).

$$\text{Sensitivity} = \text{TP} / (\text{TP} + \text{FN})$$

TP: True Positive i.e., VT/VF has been classified correctly

FN: False Negative i.e., VT/VF has been wrongly classified

Table1. Classification Result for SVM classifier

SVM Classifier			
TYPE	VT	VF	Sensitivity
VT	144	0	100%
VF	9	46	83.64%
TOTAL	--	--	91.83%

Table2. Classification Result for knn classifier

knn Classifier			
TYPE	VT	VF	Sensitivity
VT	143	1	99.31%
VF	8	47	85.45%
TOTAL	--	--	92.38%

7. REFERENCES

- [1] Felipe Alonso-Atienza, Eduardo Morgado, Lorena Fernandez-Martinez, Arcadi Garcia-Alberola, Jose Luis Rojo-Ivarez, "Detection of Life-threatening Arrhythmias Using Feature Selection and Support Vector Machines," *IEEE Transactions on Biomedical Engineering*, vol. 61, no. 3, pp 830-840, Nov. 2013.
- [2] Mohd. Afzan Othman, Norlaili Mat Safri, Ismawati Abdul Ghani, Fauzan Khairi Che Harun, Ismail Arrifin, "A new semantic mining approach for detecting ventricular tachycardia and ventricular brillation," *Biomedical Signal Processing and Control*, vol. 8, no. 2, pp 222-227, Mar. 2013.
- [3] Felipe Alonso-Atienza, Jose Luis Rojo-Alvarez, Alfredo

- Rosado-Munoz, Juan J. Vinagre, Arcadi Garcia-Alberola, Gustavo Camps-Valls, "Feature selection using support vector machines and bootstrap methods for ventricular brillation detection," *Expert Systems with Applications*, vol. 39, no. 2, pp 1956-1967, Feb. 2012.
- [4] Muhammad Abdullah Arafat, Abdul Wadud Chowdhury, Md. Kamrul Hasan, "A Simple Time Domain Algorithm for the Detection of Ventricular Fibrillation in electrocardiogram," *Springer-Verlag*, vol. 5, pp 1-10, 30 Sep. 2009.
- [5] Zhen-Xing Zhang, Sang-Hong Lee, Hyoung J. Jang, Joon S. Lim, "Detecting Ventricular Arrhythmias by NEWFM," *IEEE Transaction on Granular Computing*, pp 822-825, Aug. 2008.
- [6] Irena Jekova, "Shock advisory tool: Detection of life threatening cardiac arrhythmias and shock success prediction by a common parameter set," *Biomedical Signal Processing and Control*, vol. 2, no. 1, pp 25-33, Jan. 2007.
- [7] Anton Amann, Robert Tratnig, Karl Unterkoer, "Detecting Ventricular Fibrillation by Time-Delay Methods", *IEEE Transaction on Biomedical Engineering*, vol. 54, no. 1, pp 174-177, Feb. 2007.
- [8] Yan Sun, Kap Luk Chan, Shankar Muthu Krishnan, "Life-threatening ventricular arrhythmia recognition by nonlinear Descriptor", *BioMedical Engineering OnLine*, vol. 4, no. 6, pp 1-11, Jan. 2005.
- [9] A Amann, R Tratnig, K Unterkofer, "A New Ventricular Fibrillation De-tection Algorithm for Automated External De brillators", *IEEE Con-ference on Computers in cardiology*, vol. 32, pp 559-562, Sept. 2005.
- [10] L. Khadra, A.S. AI-Fahoum, H. AI-Nashash, "Detection of life-threatening cardiac arrhythmias using the wavelet transformation", *Med. Bio. Eng. Comput.*, vol. 35, pp 626-632, May 1997.
- [11] V.IIankumaran, Dr.S.ThamaraiSelvi, "Ventricular Arrhythmias Detec-tion using Wavelet Decomposition", *International Journal Of Computer Applications*, vol. 20, no-1, pp 11-18, April 2011.
- [12] A. S. AI-Fahoum, I I. Howitt, "Combined wavelet transformation and radial basis neural networks for classifying life-threatening cardiac ar-rhythmias", *Med. Biol. Eng. Comput.*, vol.no. 37, pp 566-573, May 1999.
- [13] Xu-Sheng Zhang, IEEE, Yi-Sheng Zhu, Nitish V. Thakor, Zhi-Zhong Wang, "Detecting Ventricular Tachycardia and Fibrillation by Complex-ity Measure", *IEEE Transactions On Biomedical Engineering*, vol. 46, no. 5, pp 548-555, May 1999.
- [14] Nitish V Thakor, Yi-Sheng Zhu, Kong Yan Pan, "Ventricular Tachy-cardia and Fibrillation Detection by a Sequential Hypothesis Testing Algorithm", *IEEE Transactions On Biomedical Engineering*, vol. 37, no. 9., pp 837-843, Sept. 1990.
- [15] S. Chen, N. V. Thakor and M.M.Mower, "Ventricular brillation de-tection by a regression test on the autocorrelation function", *Med. and Biol. Eng. and Comput.*, vol. 25, pp 241-249, May 1987.
- [16] K. Balasundaram, S. Masse, K. Nair, K. Umopathy, "A classi cation scheme for ventricular arrhythmias using wavelet analysis," *International Federation for Medical and Biological Engineering*, vol. 51, no. 1-2, pp 153-164, Nov. 2012.