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Feature Extraction and Analysis of ECG signal for Cardiac Abnormalities- A Review

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***Abstract*- This work is an attempt to discuss and investigate various techniques of extracting and selecting the vital features from the ECG signal in order to analyze the ECG signal automatically. Feature extraction, classification of feature and optimization of extracted feature are some of the common steps of automatically analyze the ECG data. Morphological and statistical features of the ECG signals play very important role in detecting the heart related diseases. Morphological features gives good result in arrhythmia classification while statistical feature are also useful because of variation in ECG signal for different patients.**

Keywords—Feature Extraction, SVM, PSO, ECG, DWT

I. INTRODUCTION

A lot of effort has been made in the past for assessing the Cardiac vascular diseases (CVD).In the past few years cardiovascular disease has emerged as one of the deadliest disease causing death all round the world. The main reason of cardiovascular disease is irregularities of heart rate. ECG (Eco-cardiogram) is one of the min tool used for recording the heart activity and characteristics or beat pattern[1-2]. Cyclical contraction and relaxation of human heart muscles produce bio-electrical signal and ECG represent these bio electrical signal. In order to record these bio electrical signal ECG devices uses electrode of varying numbers from 3-12. System having number of electrode from 12 to 120 are also available,[3].Detecting and diagnosing of CVD depends on accurate detection of ECG signal coming from the heart. Electrocardiogram (ECG) consist of three basic component, P Wave, QRS complex, T wave. Amplitude of these waves along with the duration for which these wave appear in ECG signal is shown in figure 1.

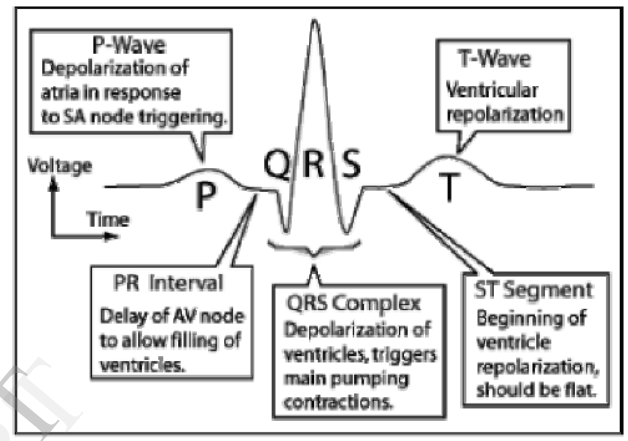

Figure 1 The normal ECG waveform.

Here P-wave is generated in the duration of atrium depolarization while during ventricular depolarization, QRS complex wave is produced. During the ventricle recovery period, T wave is produced. Various wave and ECG interval are shown in the figure given below.
Eco-cardiogram (ECG) is a very effective tool for detecting various abnormalities,state and comdition of the heart. In ECG signal, the interval between two consecutive R peaks i.e. R-R interval tell us about the heart rate(HR). The heart rate for a normal person is in between 60-100 BPM (beats per minutes). If the heart rate is greater than this normal heart rate then it indicate the tachycardia while heart rate below the normal heart rate gives the possibility of bradycardia disease. Table given below gives the amplitude and interval of various ECG waves.
Since the ECG signal recorded from different people are different and heterogeneous nature and easily affected by the noise during the recording process therefore it is very necessary to preprocess the ECG signal before detecting beats and extracting out various features. Most important feature of ECG signal is hidden in P, Q, R, S and T wave[1] . Once the features hidden in these wave are extracted out then it is not difficult to detect different kind of CVD.

TABLE 1 ECG waveform parameter

Amplitude(mV)	Duration (Seconds)
P Wave - 0.25mV	PR interval- 0.12s to 0.20s
R Wave -1.60mV	QT interval- 0.35s to 0.44s
Q Wave -25% of R wave	ST interval- 0.05s to 0.15s
T Wave -0.1 to 0.5mV	QRS interval-0.09s

Most common types of noise[4] which affect the ECG signal are-

i. Base-line Wandering
ii. Power line interference
iii. Electro-Myogram Noise(EMG)
iv. Contact Noise
v. Motion artifacts

In order to extract-out the P,Q,R,S and T wave correctly from ECG signal, it is very important to remove the noise from the ECG signal. In the past a lot of work[5] has been done for detecting the ECG beat automatically and lots of commercial software are available for detecting the beat automatically but their performance are not up to the mark. With the help of MATLAB software, some authors suggested some improvement in the existing algorithm [2, 4] by applying wavelet- transform[5,7]. These improvement not only reduced the complexity of the previous algorithm but also improved the SNR of ECG signal. Once the ECG signal preprocessing and beat detection is finished then the next phase is to classify the beat for analysis of CVD[8]. Automatic accomplishment of these steps greatly reduced the time and effort to diagnose the heart disease but also to give accurate results. Manual accomplishment of above steps require several hours and result obtained may miss the accuracy. Therefore, now a days, computer based detection and classification of beat has become necessity for correct and prompt diagnosis [2]. In the apst various method for beat classification have been suggested by different authors such as Artificial Neural Network (ANN) based[8], Maximum likelihood based[8], SVM(Support vector Machine) based[9,10] beat classification method. These machine learning based method relies on the feature extracted from past database and training of network. Since these techniques work on global environment therefore these technique may not be accurate for particular patient. Automatic arrhythmia-diagnosis system is therefore require for obtaining the high accuracy classification rate which can give good classification in case of inter-patient and intra-patient variations and hence this has become the area of current research.

II. COMMON STEPS OF ECG SIGNAL ANALYSIS

Before analyzing and extracting the feature from the ECG signal, it is very important to remove the artifacts from the ECG signal and hence following steps are necessary for ECG signal analysis-

1. Preprocessing Block- Main objective of this block is to remove to artifacts from the ECG signal like power line interference, baseline wander, high frequency noise, artifacts generated from equipment and environment.
2. Feature Extraction Block- Once all the artifacts of ECG signal is removed using preprocessing block then next step is to extract the appropriate features from the ECG signal to analyze the ECG signal accurately.
3. Feature Reduction Block- This Block is optional and not necessary in every ECG analysis technique. This block is used to reduce the dimension of feature. Reduction in the dimension of feature enhance the speed of algorithm used for analyzing the ECG signal.
4. Classifier Block- Since different diseases have different features which work as a proof of occurring that particular disease. Therefore it is very important to classify the feature after extraction. The classifier block does the same function. SVM(support Vector Machine), PSO(Particle Swarm Optimization) are some of the most common type of classifier used in this block.

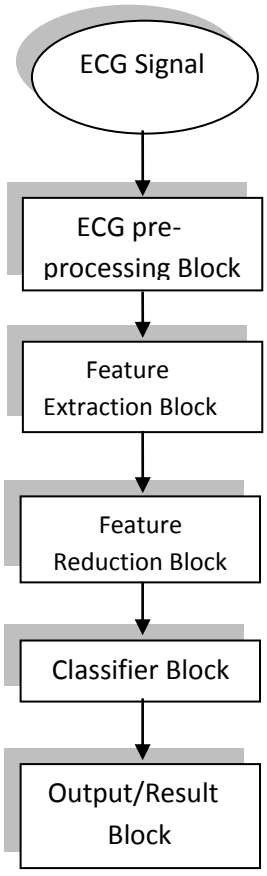

Fig.2 Flow Diagram of ECG Signal Analysis

5. Output Block- This block give the final result or judgment of the ECG analysis.It also provide and compute performance metrics.

III. PRE-PROCESSING

Removal of different kind of artifacts from the ECG signal is the main objective of the pre-processing. ECG signal is affected by different kind of noise and different kind of noises require different strategies. Thakor and Zhu[11] suggested adaptive filter based base line wander removal algorithm. Poor response of this filter in removing the noise from the ECG signal made it impractical. Baseline wandering and power line interference are two most prominent noises that affect the ECG signal to much extent[5].patient respiration is the main source of baseline wandering whose frequency lie in the range 0.15 to 0.3 Hz. Power line interference comes under the category of narrow-band noise. This noise is centered around 60 Hz and occupies the bandwidth of less than 1KHz [4]. Other then these two noises, Rest of the noises comes under the category of wide-band noise and these noise also affect the ECG signal. The hardware equipment used for acquiring the ECG signal has a ability to suppress the power-line interference but wide-band noise and base line wandering can not be suppressed by the hardware alone. Therefore some software algorithm is used for removing baseline wandering and other wide-band noise.

IV. FEATURE EXTRACTION

Extraction of various features from the ECG signal is essential steps in ECG signal analysis. Detecting P,Q,R,S and T wave (QRS complex) in ECG signal comes under the feature extraction. These wave gives a lot of information about the condition of heart which help doctors to diagnose the disease.

One of the common method of detecting the QRS complex is to use the non-linear filtering [4] which is less complex and require less time also. But this method is not able to work in case of frequency variation occurs in QRS complex and hence give poor performance in this condition. Due to the noise , frequency band of QRS complex overlap the frequency band of noise which produce false positive and negative.

Some researcher [6],[12],[13] and [14] suggested wavelet transform based denoising techniques for ECG signal. In this method, the ECG signal is first decomposed in to different frequency component and then extract the QRS complex. This method is good at preserving the phase information of the ECG signal. In his paper Dinh[19] proposed cubic spline wavelet and interpolation for detecting QRS accurately. In his paper he gave the conclusion that wavelet function which support compactness and symmetry gives the highest accuracy. Pan and Tompkins[1] in their paper found out the highest square slope during high spectral energy of ECG wave and the they found out the fiducial points. This scheme is able to finding out more fiducial points along with the actual QRS complex. They also computed two threshold adaptively and then selected highest between the two extract out QRS complex from the ECG signal. They also used search back algorithm if QRS complex is absent in certain time limit. Their algorithm give a very good result about 99.325% accuracy for MIT-BIH database[14]. The QRS complex later is used to extract out the feature of ECG signal which is used for St segment and finding out the statistical nature of the ECG signal.

Another robust method[15] which was based on the wavelet transform attracted many researcher due to its accuracy. This method is used to extract the feature which are used for arrhythmia classification. They computed six feature which are basically energy descriptor computed from wavelet coefficients for a single beat interval of ECG signal. They also used different discrete wavelet transform. They achieved about 98% accuracy on an average for classifying ventricular fibrillation and VT.
Zhao[16] presented a wavelet transform and support vector machine based feature extraction method. This is a new approach of extracting the feature for recognizing heart rhythm reliably. This method consist of three steps i.e. pre-processing, Feature extraction and classification. The feature of each ECG segment is extracted out by taking the wavelet transform and then extracting the coefficients. Auto regressive modeling is then used to get the temporal structure of the ECG. At the last step support vector machine is used with Gaussian kernel for classifying different ECG heart rhythm. The method achieved accuracy of 99.60%.

Castro[17] in his paper proposed another wavelet based approach to extract the feature from the ECG signal. In his approach he first de-noised the ECG signal by a hard and soft thresholding then he decomposed the PQRST cycle into coefficients vector with the help of wavelet function. The approximated coefficients of the last scale level are then used for analyzing the ECG pattern.

Mahmoodabadi[18] presented a Daubechies Wavelets based ECG feature extraction method. In his approach they have used multi-resolution wavelet transform. He concluded that wavelet filter whose scaling function si similar to the shape of ECG signal give better detection result. In his method he first de-noised the ECG signal then find out the peaks of the individual wave in one cardiac cycle. He claimed to achieve sensitivity of 99%.

A mathematical morphology based ECG feature extraction approach was presented by Tadejko and Rakowski[19]. The main aim of his work is to evaluate the performance of different automatic classifier of ECG signal for detecting the abnormality in beats by introducing the new feature extraction stage. In his approach he used SOM(Self organizing map) and LVQ (Learning Vector quantization)for classification. In this method mathematical morphology is used for pre-processing the ECG signal.

Saxena [20] suggested a new and efficient feature extraction of ECG signal by compressing the ECG signal. He concluded that after compressing the ECG data when we retrieved or uncompress the ECG data then it was found that the quality of ECG signal has improved a lot because of suppression of high frequency component of ECG

signal. He used ANN(Artificial neural network) to improve the compression ratio.

Discrete wavelet transform(DWT) based feature extraction of ECG signal was presented by Emran [21]. In his work he extracted important feature of ECG signal to perform classification task. With the help of mother wavelet, dialation and translation, he extracted the important feature of the ECG signal.

Miad Faezipour [22] applied hybrid approach of Pan and Tompkin's adaptive thresholding combined with wavelet peak and valley detection by which they achieved significant improvement compared to Pan and Tompkin's technique[23].

V. CONCLUSION

ECG signal carries some vital information about the heart and it is one of the important tool for the doctors to for diagnosing the heart related diseases. In the past a lot of work has been presented by various researcher to extract the features from the ECG signal so that the analysis of ECG become automate and easier. The analysis of ECG signal depends upon the accurate detection of various features of ECG signal. In this review paper some of the important algorithm of ECG feature extraction presented in the past has been discussed. From the discussion it is clear that wavelet transform is one of the important tools for extracting out QRS complex and other features from the ECG signal.

REFERENCES-

1. J. Pan andW. J. Tompkins, "A real-time QRS detection algorithm," IEEE Trans. Biomed. Eng., vol. BME-32, no. 3, pp. 230–236, Mar.1985.
2. P. de Chazal, M. O'Dwyer, and R. B. Reilly, "Automatic classification of heartbeats using ECG morphology and heartbeat interval features," IEEE Trans. Biomed. Eng., vol. 51, no. 7, pp. 1196–1206, Jul. 2004.
3. P. Zarychta, F. E. Smith, S. T. King, A. J. Haigh, A. Klinge, D. Zheng, S. Stevens, J. Allen, A. Okelarin, P. Langley, and A. Murray, "Body surface potential mapping for detection of myocardial infarct sites," in Proc. IEEE Comput. Cardiol., Sep./Oct. 2007, pp. 181–184.
4. B.-U.Kohler, C.Henning, and R.Orglmeister, "The principles of software QRS detection," IEEE Eng. Med. Biol. Mag., vol. 21, no. 1, pp. 42–57, Jan./Feb. 2002.
5. D. Zhang, "Wavelet approach for ECG baseline wander correction and noise reduction," in Proc. 27th IEEE Annu. Conf. Eng. Med. Biol., Sep. 2005, pp. 1212–1215.
6. C. Li, C. Zheng, and C. F. Tai, "Detection of ECG characteristic pointsusing wavelet transforms," IEEE Trans. Biomed. Eng., vol. 42, no. 1, pp. 21–28, Jan. 1995.
7. M. Faezipour, T. M. Tiwari, A. Saeed, M. Nourani, and L. S. Tamil, "Wavelet-based denoising and beat detection of ECG signal," in Proc. IEEE-NIH Life Sci. Syst. Appl. Workshop,, Apr. 2009, pp. 100–103.
8. Y. H. Hu, S. Palreddy, andW. J. Tompkins, "A patient adaptive ECG beat classifier using a mixture of experts approach," IEEE Trans. Biomed.Eng., vol. 44, no. 9, pp. 891–900, Sep. 1997.
9. M. H. Song, J. Lee, S. P. Cho, K. J. Lee, and S. K. Yoo, "Support vector machine based arrhythmia classification using reduced features," Int. J. Control, Autom., Syst., vol. 3, no. 4, pp. 571–579, Dec. 2005.
10. R. Besrour, Z. Lachiri, and N. Ellouze, "ECG beat classifier using support vector machine," in Proc. 3rd IEEE Int. Conf. Inf. Commun. Technol.: From Theory Appl., Apr. 2008, pp. 1–5.
11. N.V. Thakor andY. S.Zhu, "Applications of adaptive filtering to ECG analysis: Noise cancellation and arrhythmia detection," IEEE Trans. Biomed. Eng., vol. 38, no. 8, pp. 785–794, Aug. 1991.
12. J. P. Martinez, S. Olmos, and P. Laguna, "Evaluation of a wavelet-based ECG waveform detector on the QT database," Comput. Cardiol., vol. 27, pp. 81–84, Sep. 2000.
13. P. M. Agante and J. P.Marques de Sa, "ECG noise filtering using wavelets with soft-thresholding methods," Comput. Cardiol., vol. 26, pp. 535–538, Sep. 1999.
14. J. S. Sahambi, S. N. Tandon, and R. K. P. Bhatt, "Using wavelet transforms for ECG characterization: An on-line digital signal processing system," IEEE Eng. Med. Biol. Mag., vol. 16, no. 1, pp. 77–83, Jan./Feb. 1997.
15. Elif Derya Übeyli "Feature Extraction for Analysis of ECG Signals", International Conference on IEEE EMBS Vancouver, British Columbia, Canada, August, 2008
16. Qibin Zhao, and Liqing Zhan, 2005 "ECG Feature Extraction and Classification Using Wavelet Transform and Support Vector Machines," International Conference on Neural Networks and Brain, ICNN&B '05, vol. 2, pp. 1089-1092,.
17. B. Castro, D. Kogan, and A. B. Geva, 2000 "ECG feature extraction using optimal mother wavelet," The 21st IEEE Convention of the Electrical and Electronic Engineers in Israel, pp. 346-350,.
18. S. Z. Mahmoodabadi, A. Ahmadian, and M. D. Abolhasani, 2005 "ECG Feature Extraction using Daubechies Wavelets," Proceedings of the fifth IASTED International conference on Visualization, Imaging and Image Processing, pp. 343-348,.
19. P. Tadejko, and W. Rakowski, 2007 "Mathematical Morphology Based ECG Feature Extraction for the Purpose of Heartbeat Classification," 6th International Conference on Computer Information Systems and Industrial Management Applications, CISIM '07, pp. 322-327,.
20. S. C. Saxena, A. Sharma, and S. C. Chaudhary, 1997 "Data compression and feature extraction of ECG signals," International Journal of Systems Science, vol. 28, no. 5, pp. 483-498,.
21. Emran M. Tamil, Nor Hafeezah Kamarudin, Rosli Salleh, M. Yamani Idna Idris, Noorzaily M.Noor, and Azmi Mohd Tamil, "Heartbeat Electrocardiogram (ECG) Signal Feature Extraction Using Discrete Wavelet Transforms (DWT)."
22. Miad Faezipour, Student, Adnan Saeed, Suma Chandrika Bulusu,Mehrdad Nourani, Hlaing Minn, and Lakshman Tamil IEEE, september 2010 "A Patient-Adaptive Profiling Schemefor ECG Beat Classification" transactions on information technology in biomedicine, vol. 14, no. 5, pp. 1153-1165.
23. Jiapu Pan and willis j. Tompkins, senior member, IEEE, march 1985 "A Real-Time QRS Detection Algorithm" IEEE transactions on biomedical engineering, vol. Bme-32, no. 3, pp. 230-236.