R PEAK DETECTION USING APPROXIMATE ENTROPY

Dissertation

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By

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DECLARATION

I hereby declare that the dissertation proposal entitled, " R PEAK DETECTION USING APPROXIMATE ENTROPY" submitted for the M.Tech Degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: Rajkiran Saini

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CERTIFICATE

This is to certify that Rajkiran Saini bearing Registration no. 11312920 has completed objective formulation of Dissertation titled, "R peak detection using approximate entropy" under my guidance and supervision to the best of my knowledge, the present work is the result of her original investigation and study. No part of the Dissertation has ever been submitted for any other degree at any University. The Dissertation is fit for submission and the partial fulfilment of the conditions for the award of the Degree of Master of Technology

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ABSTRACT

An R peak detection algorithm based on the ApEn is proposed and tested on 20 ECG signals obtained from MIT-BIT analysis data base from Physio.net/Bank/ATM. Effect of 'r' on sensitivity and specificity of peak detection is analyzed. It is found that value of ApEn changes with increase in value of 'r' factor and then decrease with increase in the value of 'r' factor. Heart Rate Variability is defined as the analysis of all the functions of human heart and their respective parameters like Heart Rate , ECG signal, Peak Detection and Diseases diagnosis, is the main part of the biomedical signal processing of the Heart. Some of the methods shows 99 % accurate results in term of sensitivity of the signal and are very efficient and perfectly ideal for real time analysis of large number of ECG data ,but some-how they faced the some errors like ' largest time error or delay error '. Hence, to remove this error new techniques are used like entropy based methods, which are defined as degree of randomness in any signal.

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LIST OF ABBREVIATIONS

ApEn	Approximate Entropy
Aztec	Amplitude Zone Time Epoch Coding
Bp	Blood Pressure
Bsp	Biomedical Signal Processing
Bvp	Blood Volume Pressure
Ecg	Electocardio Gram
Emd	Empherical Mode Decomposition
Emg	Electromyogram Signal
En	Entropy
Fft	Fast Fourier Transform
Hbr	Heart Beat Rate
Hrv	Heart Rate Variability
Hpf	High Pass Filter
Hz	Hertz
I.E	That Is
Ieee	Institute Of Electrical And Electronics Engineers
K	Boltzmann's Constant
Lpf	Low Pass Filter
'N'	N Variable
No.	Number
PQRST	Templates Of Ecg Signal
PCG	Phono Cardiogram
PPG	Photo Plethy Smography
Rr	R Peak To R Peak
R	Threshold Factor
SmEn	Sample Entropy
Tp	Turning Point
Tp	True Positive
Tn	True Negative
Fp	False Positive
Fn	False Negative

CHAPTER 1
INTRODUCTION

Today, one of the major requirements of a physician is to analyze specific data of the patients and logically correlate it with information about signs and symptoms, disease and treatment. Very often this specific data or signals, is in the form of signal recorded from a patient's body, which has to be properly examined and analyze before any therapy can begin, for this , the tool required are based on the techniques of digital signal processing i.e. Biomedical Signal Processing, that specific signal is called as biomedical signals. Basically, biomedical signal processing deals with the development of different signal processing methods and algorithms that extract the useful information from the data provided [1][2][3].

Biomedical Signal Processing (BSP) is a bundle of many different techniques which help in reduction and deduction of the different signals according to the specific data given. Heart Rate Variability (HRV) is the basic function of BSP which deals with the heart and its various parameters which helps to detect the different diseases [11].Heart disease is an emotive subject that undoubtedly attracts a great deal of attention of not only those who are charged with the delivery of health care but also the policy planners. It is therefore not suprisisng to find new, technology-based investigation methods being developed in cardiology for better diagnosis and therapy.

1.1 Heart Rate Variability (HRV)

Heart Rate Variability is defined as a term which helps to calculate the beat to beat or interval to interval variation with respect to time between two heart rates. HRV represent the best achievement in the field of Biomedical Signal Processing, due to its easy calculation of various parameters and their values. This technique does not, only provide relevant information about cardiological signal but also very helpful in research and in studies. It is most relevant in finding variation in 'RR interval' of an ECG signal and also analysis the various waveforms like ECG (Electocardio Gram), PCG (Phono Cardiogram) and EEG (Electroencephalo Gram) signals [1][11].

It calculates the high and low frequency components of the signal and checks, is their any disorder or any other problem in heart? It also helps in identifying many problem with respective measurements and standard algorithms related to heart.

This method checks the BP (Blood Pressure), BVP (Blood Volume Pressure) and PPG (Photo Plethy Smography) signals. It uses various methods like geometrical methods, mean methods, time domain methods, frequency domain methods, time-frequency domain parameters, statistical parameter, mean, median, average, standard deviation, sigma, variance, moments calculation of heart rate, frequency domain, time-frequency domain methods which defines it in terms of pulse rate, heartbeat.

ECG waveform helps in calculating the frequencies of the different signal and then recover those signal. It analyze them by defining various diseases on the basis of their frequency components, like diabetics, cervical, heart attack, heart values disorder not proper flow of blood in the vessel. HRV is strong predictor of acute myocardial infarctions. It helps to detect heart rate at any sample in any time intervals between successive and normal complexes.

1.2 Heart

The heart is a muscular organ about the size of a fist, located just behind and slightly left of the breastbone. The heart pumps blood through the network of arteries and veins called the cardiovascular system [3].

The heart has four chambers:

- The right atrium receives blood from the veins and pumps it to the right ventricle.
- The right ventricle receives blood from the right atrium and pumps it to the lungs, where it is loaded with oxygen.
- The left atrium receives oxygenated blood from the lungs and pumps it to the left ventricle.
- The left ventricle (the strongest chamber) pumps oxygen-rich blood to the rest of the body. The left ventricle’s vigorous contractions create our blood pressure.

The coronary arteries run along the surface of the heart and provide oxygen-rich blood to the heart muscle. A web of nerve tissue also runs through the heart, conducting the complex signals that govern contraction and relaxation. Surrounding the heart is a sac called the pericardium. Figure 1.1 shows human heart.

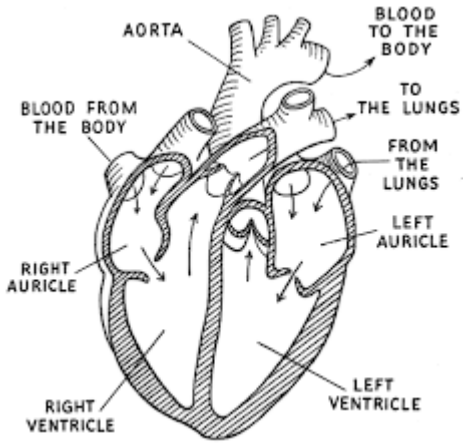

Figure 1.1: Human Heart

1.3 ECG

Electrocardiography (**ECG** or **EKG)** is defined as the term of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle depolarizing during each heartbeat. Basically ECG is a continuous record of voltage changes that reflect the cycle electro-physiologic events in the myocardium [5].

It is usually recorded from the skin (this is called surface ECG) using electrodes that are connected to a galvanometer. It also record the signal from electrodes positioned in the esophagus in the chamber of the heart or directly from myocardium, named as T-ECG signal.

1.3.1 ECG Generation

The time varying motion of the cardiac vector produces the body surface ECG for one heart beat. With each heart beat this ECG signal forms a series of deflection that are labeled as P,Q,R,S,T and U. The P wave reflects artial depolarization while the Q,R and S waves (QRS complex) reflects ventricular depolarization. The T wave corresponds to the ventricular

replorization .The U wave is indeterminate origin. The PR interval, forms from the onset of the P wave to the onset of the QRS complex, reflects the time required for the conduction of the cardiac impulse from the SA node to the ventricles. The time required for both ventricular repolariztaion and depolarization is shown by QT interval, which starts from QRS complex interval and stop at end of the T wave [4].

The ST wave represents time duration , when the complete depolarization of the ventricular occurs, where the TP segment corresponds to the time period when heart is completely reploarized. For normal recording of ECG, which is a plot of voltage versus time, a calibration of 10 mm per mv and a paper speed of 25 mm per second is used.

The electric activity of heart produces multiple depolarization and repolarization dipoles which when summed can be thought of as producing a single dipole vector. This vector may be assumed to be present at tharox.

Its position with the variation in time relates to the origin of the body surface ECG signal and gives rise to the positive and negative deflection of the waveform.

Step 1: The slow moving depolarization of the atria that begins at the SA node gives rise to P wave.

Step 2: The signal is delayed in AV mode, which give rise to the isoelectric region after the P wave. As the purkinje system starts delivering the stimulus to the ventricular muscle, the Q wave its appearance.

Step 3: A rapid depolarization of the ventricular muscle is responsible for the production of the fast moving vector which produces the R wave. The peak of R wave is attained when most of the cells are depolarized.

Step 4: The final phase of the ventricular depolarization occurs as the excitation spreads towards the base of the ventricles give rise to the S wave and then the T wave.

Figure 1.2 shows the standard ECG signal of 1 minutes duration and 9000 samples at 360 Hz and Figure 1.3 shows the different interval in the ECG signal.

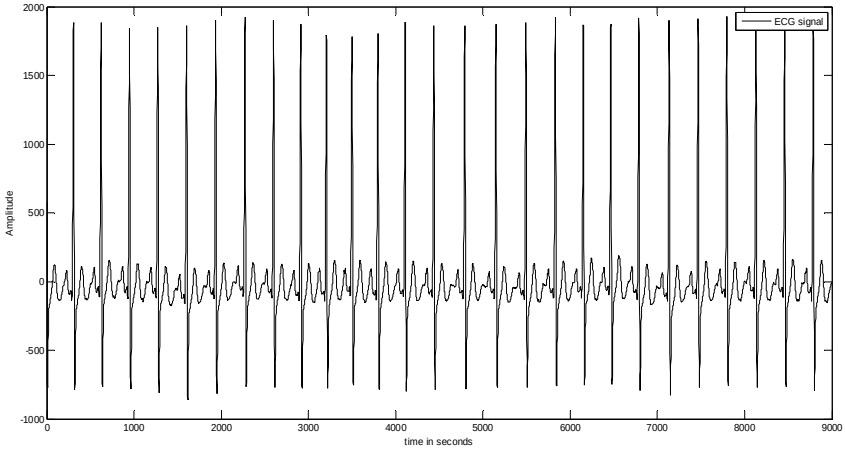

Figure 1.2 : A standard ECG signal

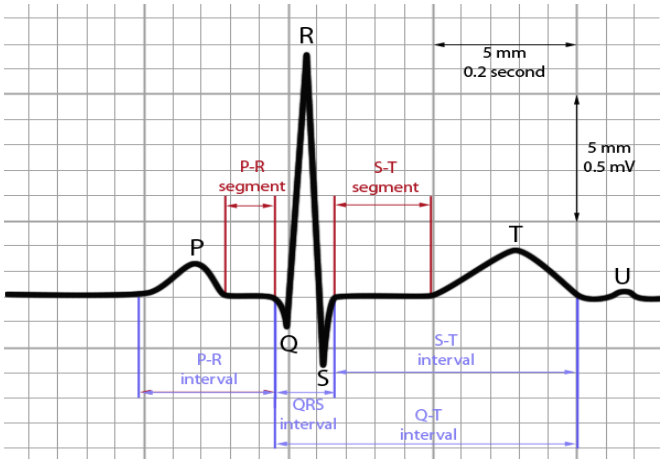

Figure 1.3: Segments of ECG signal

HRV plays a vital role in the detection of different peaks and intervals in the ECG signal, it helps in

1.1 R peak detection

1.2 Heart rate measurements

1.3 Detection of frequency (LPF and HPF)

1.4 analysis of Blood pressure volume

1.5 calculation of heart beat with respect to respiration and heart rate (flow of blood)

1.4 R Peak

R peak is the basic important peak in the ECG waveform. R peak has higher voltage level as compared to other peaks in the ECG signal and it is one of the significant and easily detected peak because of less affected by noise and having voltage value greater than standard threshold value. R peak detection algorithms provide better results of detection of this peak as compaired to the other ECG peaks and waveform. The contraction of ventricular muscles in quick level from downward to upward results in a sharp and tall QRS peak with amplitude 1microvolt and of 80-90 time duration per second which later suppress the Q and S peak with specific threshold value, hence resultant R peak is shown in the result.

The main application of HRV is to detect the R peak in the ECG waveform, while taking ECG of any specific patient, physician encountered with many different problems like irregularity in the peaks, different frequency levels, error in time-frequency components, error in recovered ECG waveform after filtering, So to overcome all these problems, researchers introduced many new methods to get accurate results of R peak and important parameters for analysis and future use. Figure 1.4 shows R peak in the standard ECG signal.

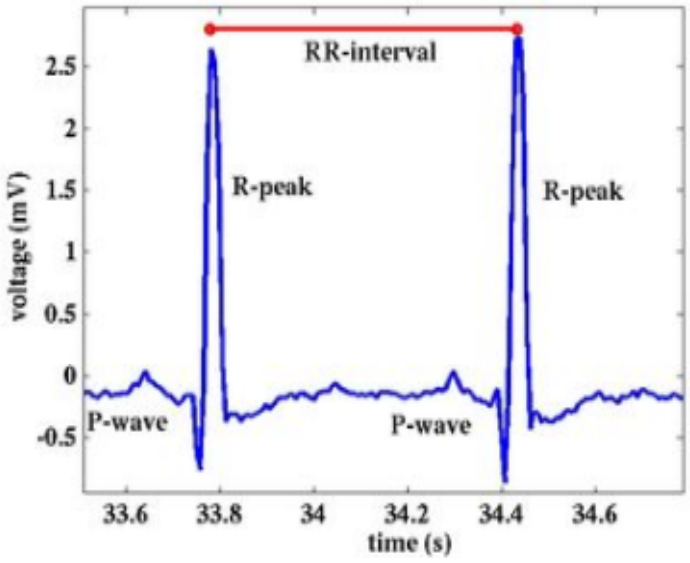

Figure 1.4: R peak in ECG

1.4.1 Methods to detect R peak

There are 'N' numbers of methods to detect R peak Searcher in the any ECG signal as shown in Figure 1.4

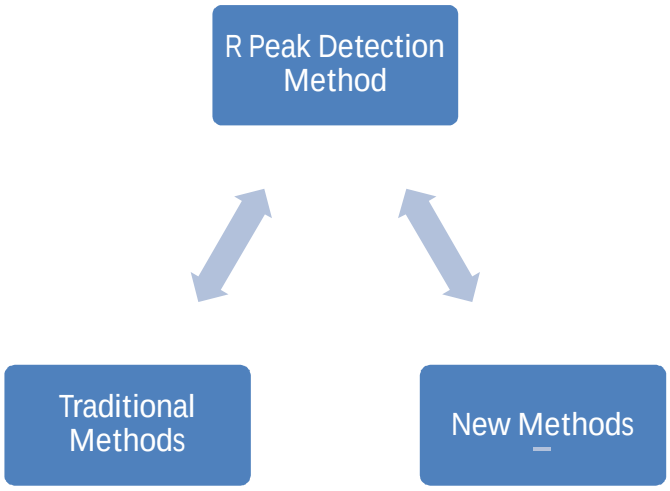

Figure 1.5: R peak detection methods

A) Traditional Methods To Detect The R Peak In ECG Signal

A.1 Pan Tompkins Method

This method is introduced in 1960, which is used to detect the QRS peak and then later applying the threshold level for suppressing the Q and S peak helps to detect the R peak in the input ECG signal. The basic algorithm of Pan-Tompkins is as shown in figure1.6. In this algorithm, input is given through the band pass filter and then differential of the filtered output is taken.

Figure 1.6: Pan Tompkins's algorithm

After differential of the signal, it follows next step by taking square of the resultant and forming a quadratic equation and the use of moving average window integrator shows QRS waveform. A specific threshold is applied on resultant QRS waveform and it shows the level, in which Q and S peaks are suppressed and only R peak is shown. This method is do not show accurate location of R peak and hence results are not appropriate in terms of sensitivity and specificity of the ECG signal, hence this method is not used now [7].

A.2 Double Differential Method

This method is the advance version of Pan Tompkins methods, as it overcome its the demerits. In this method, a second level differential is taken instead of first order derivative of the filtered output, resulting in more accurate quadratic equation which shows accurate value of frequency and time interval duration of the R peak. But this method do not accurate results in term of peak detection , when highly noised ECG signal is taken. It do not suppress S peak, and results in wrong peak detection by showing S peak as R peak in next time interval.[9].

A.3 High Pass Double Differential Method

This method is later introduced by the researchers to overcome the demerits of Pan Tompkina method and Double Differential methods, simply by combining their output results as 1 common output. In this, ECG signal is differentiate with respect to 1/32 level of derivatives, so that all the noise present in the inputs signal is removed automatically. Hence, it gives directly R peak, with 70% accuracy in term of sensitivity of the signal but still do not show 90% sensitivity of the signal. It shows more error rate in terms of detection of accurate peak.[11].

A.4 Threshold Method

This is the very simple method derived to get desired R peak with 80 % accurate results of sensitivity of the signal. ECG signal is passed through filters, to remove noise then a first threshold level is set to suppress P wave, later follows a another threshold level to suppress T wave. QRS wave is shown in the output results. R peak is detected by another threshold level to suppress Q and S wave. Although, this method is very simple in implementation but do not

shows very effective results when single hand movement of patient causes variation in the ECG signal and results in sharp T wave which is not suppress by threshold levels, results in false R peak in same time interval.[12].

A.5 Filtering Method

To overcome the demerits of threshold method, filtering method is introduced, which passes the ECG signal from high pass filter and band pass filter. This helps in removal of noise and particular frequency levels peaks and shows the results as highest peak i.e R peak in the output.

A.6 Turing Point Method

T-Point or Turning Point (TP) algorithm provides the R peak by passing ECG signal through filter and then applying compression technique on it. The recovered ECG waveform is also obtained by this algorithm. In this three levels of ECG signal are set and their respective past samples are taken and predict their future samples, later to find their relationship so that it will set appropriate level. After filtering, R peak from the desired signal is taken out, these three sample value or set shows compression of the ECG signal and then recovery of the ECG (new ECG signal) from the predicted values and threshold level.[22].

A.7 AZTEC Method

This method is improved version of TP algorithm, resulting in accurate detection of R peak and recovered ECG signal, without showing the variation in past and predicted values of the three samples taken from input ECG signal. It gives only peaks without any desired information like location of peaks, beat to beat calculation, error rate of the signal. It will take two samples, first sample value is stored in random variable and next sample values are predicted. These two samples are then compared and new peak is detected. This method shows very large error rate for noisy ECG signal.[1].

A.8 Time Domain Methods

Time Domain analysis gives the result of the ECG waveform based on different parameters like mean, median, moments, variance, standard derivation of the ECG signal and calculate

the desired result of the ECG waveform. It do not shows the frequency information of the signal, also do not calculate low and high frequency level of the signal which is used to compare with the original results to detect the various problem like BP problem, lowering heart rate, hence stated in the demerits of this method.[2].

B) New Methods To Detect The R Peak In ECG Signal

B.1 ApEn

Entropy means loss of information, to calculate the loss of information from any desired waveform, Approximate Entropy (ApEn) is used to calculate the randomness of the signal and finding the accurate range or value of ‘r’ threshold value in standard data length ECG signal to get more randomness. In this ‘r’ and ‘m' are predefined parameters which are essential for the calculation of entropy analysis. It is the rate of information production [2][21][22][3][5].

B.2 Adaptive Methods

Adaptive filter method is used to detect the desired ECG signal using Least Mean Square method in which a mixed signal is taken as input signal, compose of ECG signal and additional random noise. After comparing with desired ECG signal, a new waveform of ECG signal is formed and error or noise signal is removed from it, hence its results are taken for the medical purpose.

This method is very useful to remove error or noise signal from the specific ECG signal and information is also not loosed, specific information is taken for future use. This method shows 80% accuracy in terms of specificity of the signal up to some limits. It will shows good results till type of the noise is added in the ECG sample is known and then a threshold factor is applied on it [27].

B.3 Advance Filtering Method

Using Advance Filter Methods, it simply uses the high order filter to remove the randomness from the ECG signal and remove the unwanted peaks from ECG giving the only desired peaks in the output, helps in detection of R peak [26].

B.4 Wavelets

In Wavelets Transform, the detect of desired waveform is done by using HAAR Transform in which a random signal is taken as input signal and then dividing the signal into two parts i.e descriptive and analytical part. A threshold value/level is set to make the descriptive part as zero, which contains only high frequencies or noise or non-informatic part of the signal. Only low frequency part of signal is left i.e. analytical part.

Then, it recovers the signal using Inverse HAAR Transform and make them saving all the information of the signal, hence generate a new accurate ECG signal.

These all methods are used to find the R peak in the ECG signal which is used for many different purposes, these methods helps to find the more relevant information regarding desired signal and their respective usage, diagnosis of the different disease are done and required medicines prescribed to cure them.

At last, it is concluded that detection of R peak is very easy as it contain high frequency and is very sharp peak shown in the standard ECG signal. This helps to compare the latest and traditional methods, to detect the peak and find accurate results up to 89% in terms of sensitivity, with very less error rate that can be neglected.

1.5 Entropy

Basically Entropy is defined as the randomness or degree of disorder or fluctuation in any signal or in any sample in the field of digital signal processing. Sometimes entropy is miss-understood with respect to energy, but entropy calculates the lack of order in any system or signal. It is also defined as the order in which a system or thermodynamic system can be arrange with respect to the lack of degree in that samples [3][4].

There are many different types of entropy methods that are used to detect ‘R peak’ from different types of noisy or standard ECG signal.

Mathematical, Entropy is stated as multiplication two product i.e multiplication of Boltzmann’s constant and logarithmic values of the input series which are having lack of order or degree.

$$\mathbf{Entropy} = \mathbf{K} * \mathbf{x(n)} \quad (1.1)$$

Where x (n) defined as possible outcome of series having disorder degree.

1.5.1 Types Of Entropy

There are different types of Entropy as shown in figure 1.7, which shows different values for the disorder in the signal.

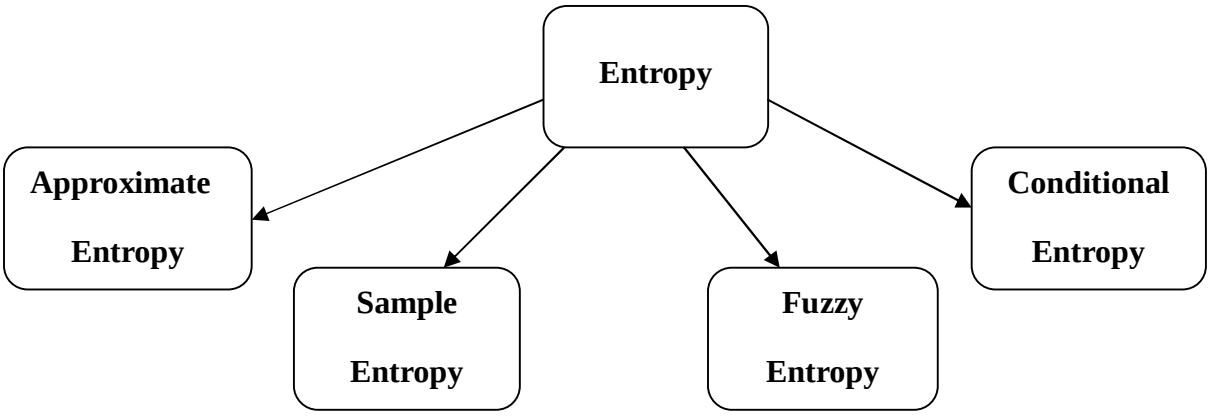

Figure 1.7: Types Of Entropy

A) Approximate Entropy: ApEn (Approximate Entropy) is defined as method or technique which helps to get a single value for amount of disorder of signal or unpredicted fluctuation and the regularity or proper degree or non randomness of the signal [3][4][14].

Approximate Entropy is a statistic that can be used as a measure to quantify the complexity or irregularity of a signal, it was first proposed by 'pincus' in 1991 and was then used mainly in the analysis of HRV and endocrine hormone release pulsatility. It is also used to analyze various other physiological signals such as ECG, the ECG and respiration. Its application is spreading rapidly as fast as possible. The following silent features of ApEn make it attractive for using signal processing:

1. Robustness estimate of ApEn can be obtained by using shorter data in range 100-5000 points, with 1000 points are used mostly.

2. It is highly resistant to short, strong transient interference.

3. The influence of noises can be spread by properly using the relevant parameter in algorithm.

4. It can be applied to both deterministic and stochastic signals and to their combinations.

The first three properties make it suitable for the analysis of experimentally obtained, noise-contaminated short data. The last property is beneficial for biosignal analysis, because of biological system is so complex that the output usually consist of both deterministic and random components.

A.1 ApEn Algorithm[4]

Step 1: Form a time series of data from X1,X2,X3……XN. These are 'N' raw data values from measurement equally spaced in time.

Step 2: Fix 'm' , an integer, and 'r', a positive real number. The value of m represents the length of compared run of data, and 'r' specifies a filtering level.

Step 3: Form a sequence of vectors from U1,U2,U3,…….U(N-M+1), in 'r(m)', real m-dimensional space defined by

X1= [U(i+1),U(i+2),…….U(i+m-1)]

(1.3)

Step 4: Use the sequence X(1),X(2),X(3),……X(N-m+1) to construct, for each 'I', 1<i<N-m-1, Now

$$C_i^m(r) = (\text{number of } x(j) \text{ such that } d[x(i), x(j)] < r)/(N - m + 1)$$

(1.4)

in which d[x,x*] is defined as

d[x,x*]= max^a| u(a)-U*(a)

(1.5)

Step 5 : Define

$$\Phi^m(r) = (N - m + 1)^{-1} \sum_{i=1}^{N-m+1} log(C_i^m(r))$$

(1.6)

Step 6: Define approximate entropy Apen as

$$\mathbf{ApEn} = \Phi^m(r) - \Phi^{m+1}(r).$$

(1.7)

In Approximate Entropy, a Standard ECG signal is labeled as X1 and X2, of different sample. X2 is predicted values which are having any random values with the probability of 1/2 value per sample to be chosen, here no mean or variance will be calculated as these parameters will not help in finding, how to distinguish the two respective series given by user or any other information by any person, even calculation of the matrix or rank order like traditional methods to find R peak will also stated as failed methods to differentiate both random series [11].

Even traditional methods like geometrical or arithmetic methods are also showing no results to find the difference in them even Haar wavelets, also give different result but somehow up to 50% accurate in term of sensitivity, but not properly 100% resultant is achieved.

First series is that series which is consists of perfectly desired or known sample numbers while second series is the purely random series, whose samples and number of samples is not known which result of the predicted values is by the past samples [15].

Then a threshold level or filtered level is set named as ‘r’ which tell that which value should be store to matrix, values greater than r will be stored but values less than r will not be stored , they are discarded .

After this, only particular values are store beyond that threshold level, its result is shown in form of a matrix having zero diagonal values which create a error in the calculation ,which will be resolved using matrix transform using rows and columns operation. If, the Miss-matching of identical zero matrix occur then it will result in the demerits of the ApEn as it

will make final outcome to be latterly independent of record length which will give false results also, somewhat wrong values of peak occurrence or periodicity of signal and also it will result in very poor consistency as it will result in no higher peak.

So, matrix transform is important in ApEn algorithm, then later a 'i' value will be set as limit to be from first sample till n no of samples and giving proper value of each sample later, log of the specific samples is taken up to n levels and the ApEn is calculated by taking difference of the logarithmic values of the two specific sequence up to n level [22].

This ApEn results in the very small value showing the regularity and predicted samples of the signal, if the value of ApEn is very large it shows that there is still fluctuation in the signal and still randomness is not removed and periodic signal is not received as main output.

It will formulate a single peak in single frames which represent the highest peak having highest entropy value among other peaks in that particular frame only; hence we will get entropy values of the signal.

B) Sample Entropy: Sample entropy is advance form of ApEn Entropy , it is defined as negative natural logarithm values of any signal which estimates its conditional probability of length 'L' which matches the tolerance 'r' for finding the random change in the signal.

C) Fuzzy Entropy: Entropy of fuzzy set is the degree by which $M \cup M^c$ is a subset of $M \cap M^c$ i.e. Entropy is a measure by which whole is a subset of its own part. Sub-set hood in non-classical fuzzy logic is a degree statement.

D) Shannon Entropy: Shannon entropy is one of the most important metrics in information theory. Entropy measures the uncertainty associated with a random variable, i.e. the expected value of the information in the message (in classical informatics it is measured in bits).Shannon entropy allows to estimate the average minimum number of bits needed to encode a string of symbols based on the alphabet size and the frequency of the symbols.

F) Conditional Entropy: In information theory, the conditional entropy (or equivocation) quantifies the amount of information needed to describe the outcome of a random variable 'Y1' given that the value of another random variable 'T1' is known. Here,

information is measured in Shannon's, Nat or Hartley. The entropy of 'Y1' conditioned on 'T1' is written as

$$\boldsymbol{H = \frac{Y1}{T1}} \qquad (1.2)$$

1.6 Organization of the Report

This report includes overview of existing technique which are investigated and are implemented with respect to different samples (input data) by different researchers. The theory and comparisons study of all methods are studied regarding R peak detection methods .This report is organized as follows:

In the chapter 2, it includes the brief introduction about the new emerging technology, i.e. Detection methods. The literature survey is done in this chapter. The entire literature survey is based on the following papers taken from various organizations such as IEEE.

In the chapter 3, it represents the problem formulation and objective and scope of the study.

In the chapter 4, it includes the methodology of the work.

In the chapter 5, it contains various results of the methodology that has been implemented with respect to different samples which are taken as input data , in Matlab.

In the chapter 6, it contains the summary and conclusion of the work done.

CHAPTER 2

LITERATURE REVIEW

This chapter consists of an introductory part and original publications. The entire literature Survey is based on the following papers taken from various organizations such as IEEE.

2.1 Overview Of 'R Peak' Detection

In this literature survey, R peak detection research is a significant part of it. There are many methods which are introduced to detect the R peak directly from the ECG waveform or from QRS complex waveform with accuracy of 98.9% in sensitivity of the signal with very less error rate. Sarabjeet Singh Mehta proposed a method which deals with the R peak detection from QRS complex using entropy and probability method with 98.9% accuracy in peak detection i.e true positive number of R peak and also differentiate the non-QRS and QRS peaks. Later, richman and moorman shows the detection of randomness or lack of degree by using ApEn and Sample Entropy. Z.wang shows same results by suppressing P, T wave in the ECG signal. Task force paper deals with the HRV analysis of the heart and its parameters, which helps to diagonize many different diseases related to heart. Pan Tompkins method is introduced in 1960 which is the first method to detect R peak using threshold factor and derivative of the signal. This methods shows many demerits which are improved by the double differential derivates and filtering methods which shows 80% accurate result in sensitivity and 76% in specificity of the input signal, but this method do not show any effective result for highly noised ECG signal. Benmalek M. states that ECG signal's noise can be minimize using bandpass filter and baseline wandering which results in removal of dc components and R peak is detected easily without any interference of noise and accurate location of peak is seen. Many more researchers used different methods to detect the R peak, along with differential and thresholding and haar transform methods, but showing some error in the false negative and false positive and true negative values which gives 3% error in the detection of the R peak. New methods are also introduced which shows 0.02 % error rate of the peak detected and shows 98.8% accurate results in sensitivity of the signal[1][5][7][9].

2.2 Review Of The Research Papers

Sarabjeet Singh Mehta, Nitin Shivappa at all (2007) describes about the development of entropy methods for HRV analysis and R peak detection using 12 leads, here entropy of each and every peak is calculated and normalized using power spectral density. QRS and non QRS peaks are differentiate using K-mean clustering methods. This helps to check fluctuation and finds the desired peak, but this shows large no. of errors like true false detection and false true detection. It shows 3% error rate in detection of peak[3].

Richman and moor man at all (2013) explains the main difference between the ApEn and SamEn, using same ECG signal And compare their results. It also explains how ApEn is best with less error and accurate peak is detected which is checking every change in every slope of ECG signal. This provides the 98% accuracy in sensitivity value of the signal but not sufficient accurate values of true positive and randomness of the signal. It states that ApEn shows better result than SamEn, by showing more randomness and fluctuation in the output results and cover more area. It shows one single value of the both entropy methods of many different samples and then by finding their mean, it shows the variation in both the entropy methods [4].

Natalia Arzeno, Chi-snag poon at all (2008) deals with the improved results to calculated the R peak detection using pan Tompkins methods and advance Hilbert transform, hence it makes a new method that is named as hmiltion Tompkins method, which helps to compare the result with traditional methods and get the accurate R peak from desired ECG signal. These results are very useful in the HRV analysis and to diagnosed the different diseases. These results show 99.1% accurate true positive value of the R peak and 0.02 % error rate of the detection method [5].

Z.S. Wang and JDZ Chen (2011) deals with the detection of the R peak from the ECG signal by suppressing the p and T wave, using particular threshold values. These values defines the particular R peak from the QRS peak, by selecting the particular value or filter value to suppress the Q and S peak only [6].

Task force (1996) deals with the HRV analysis and various methods to calculate the frequency components of the signal, by using all time and frequency methods i.e linear and non-linear domain methods to check its variability in the frequency components to detect the QRS peak and other peaks and heart rate with different values[7].

Pan Tompkins (2012), it is the improved form of the pan Tompkins method (1960). It is using the digital filters to overcome the error like baseline wandering and power line interference, this will be giving 99% accurate result in sensitivity of the signal but do not show the accurate delay error or time needed for response[8].

Meyer, Carsten, Philips Res. Labs (2006), R peak and QRS peak is considered most important parameters of the ECG signal for HRV analysis. Author discussed about the many introduced methods for peak detection but it stated that at different steps or parameters each method is failed so, automatic detection method is discussed in this. Here the improved pan Tompkins methods is discussed with wavelet algorithms, with 88% accurate results of specificity of the signal but shows error in sensitivity of the output signal[10]

Bushra j. at all (2010), in this paper explains about the ECG signal and its analysis results and states that ECG signal is used to check cardiovascular changes in body and helps to detect the different diseases. R peak detection is most due to its high voltage level and amplitude and spiked nature. Hence, R peak automatic detection helps in diagnosing the different diseases and r peak is detected using k-mean clustering algorithms which forms the matrix and hence divide the signal into QRS wave and non QRS wave into two parts an then calculate their probability at every slope, hence by applying threshold it find outs the R peak from the signal[11].

Chatlapalli (2005) states that ECG signal is very important and is a low cost tool that can detect any disease related to heart by detecting simple parameters like frequency components and time frequency parameters, Accurate detection of QRS peak and R peak, which provides the essential data. Data is taken from physio.net and HRV analysis is done. This paper compare the results of normal ECG peak and random ECG signal in young and children , find their R peak and compare the change in peak and develop the results in matlab. It shows the randomness in the ECG signals of young and old persons[12].

Alexandridi A.(2008), This paper deals with the new filtering techniques in pan Tompkins to get improve results. Haar Wavelet is used as band pass filter produce the integration phase of pan Tompkins methods and shows band pass approach and also its hardware implementation is very cheap and cost is very low and manageable also and there is no need of multiplication[13].

Nimunkar (2007), In this paper author discussed about the R peak detection method in ECG signal having noise like Electromyogam (EMG), in this EMG is modeled as white Gaussian noise and its respective SNR ratio is calculated which is from range -10 to – 20 DB and R peak results are taken directly using Pan Tompkins methods and hence are improved. EMD technique is used to filter the noise from it and low pass filtering approach is used and then results are compared with the existing methods and errors are compared, this method shows enhancement in the R peak results[14].

Miller S. at all (1997), it gives the detailed description of the about the use of entropy methods to find the accurate values and apply it on the R peak detection this shows the main change in the previous results and hence shows its improvements in the resulted outcome[15].

Benmalek M. (2009), This paper deals with the study of the effective R peak detection in the complex QRS peak/wave in ECG (random ECG) signal , using differential and integration methods using different order. This random study is made by combination of two different algorithms into one main algorithm, here the preprocessing of the algorithm is defined as filtering method by minimizing the error or noise in the ECG signal and then calculating their respective differential. Then, integration with desired order of filter maximum 5 ordered filter is used which gives 99.5% specificity of signal but shows slope error and wrong values of the slopes at some distance[16].

Martinez JP (2004), This paper shows the results of developed ECG signal having robust single lead using wavelet Transform (WT) , in this firstly QRS wave is detected and these peaks are detected by using non-linear methods and hence it results in suppressing of the T and P waves and later Q and S waves using particular threshold values[17].

Ki H. Chon, Christopher G. Scully, And Sheng Lu – (2009), In this paper, they described approximate entropy in relation to with the all other entropies, with respect to all signals to compare the results, giving accurate results in all case. Author keeps the larger value of variable 'm' i.e. desired length of the compared data to be run, which results in large matrix and hence showing the calculation for the changes in the signal at every respective point and their values are being compared with each other showing which signal has high noise present in it and how much information is stored in which part of the signal[18].

Sheng Lu, PhD1, He Zhao, - (2008), In this paper, they stated that HRV is a very important parameter and is non-invasive in nature and tells the various information about the human heart and its behavior and respective measures to check, with different outcomes and respective information. In this method the author tells about the photoplethysmo graphy which deals as another way to calculate the HRV information rather than the other methods like periodiogram, standard derivation, variance, skewness of the signal[19].

The all values of other signal with respect to the main variable , this method shows the result up to 90% result in sensitivity of R peak same as other methods in very less time without any loss of information from the signal regarding the time –frequency analysis of the signal

P Castiglioni, M Di Rienzo(2008), In this paper author make comparison between different results of approximate entropy by varying the value of r. In some cases, it is found that all values of r in the 0.1-0.25 range give different approximate entropy calculations and also r max(0.25) drastically vary from suggested range that is r=0.2. Hence, they conclude that r is critical parameter even in heart rate variability analysis[20].

Jennifer M. Yentes, Nathaniel Hunt, Kendra K. Schmid, Jeffrey P.Kaipust,Denise, Mcgrath And Nicholas Stergiou(2012), they concluded that especially for short data lengths n<=200 both approximate entropy and Sample Entropy are enormously sensitive to parameter choices. They have taken length of data sets(N) to be 200 and m to be 2 and examine values of r for parameter selection with extreme caution. Based on their findings, they concluded that that Sample Entropy is more consistent for short data lengths and; is less sensitive to changes in data sets and very less problems in comparative consistency [21].

Weiting Chena, Jun Zhuang, Wangxin Yu, Zhizhong Wang(2008),They made comparison between Fuzzy En, ApEn and SampEn and their level of similarity is based on hard boundary of ApEn and SampEn heavy side functions. They depict high parameter selection sensitivity and would be illogical in case of tiny parameters. Bringing in the concept of fuzzy sets, they form a new measure Fuzzy En. The fuzzy functions are flexible and have continuous margins which guarantee the legality of Fuzzy En at minute parameters. The more details obtained by fuzzy functions also make Fuzzy En a more accurate entropy definition than ApEn and SampEn. On top, new fuzzy entropy is better than ApEn and also SampEn as it provide consistent results and shows less dependency on data lengths contaminated by noise[22].

Yongli Chen,(2005), In this paper, author represent a new method to find QRS peak from ecg waveform using new techniques named as mathematical morphological and envelope, they shows the result for false negative and false positive for the different ecg signal, first removing the baseline wandering, then using envelope method they shows 0.0123 error in the signal with very less number of false negative peaks in the final results[23].

A.farabad at all (2015), They deals with the detection of R peak in any standard ECG signal using Hilbert transform and advance thresholding concept, it deals with the performing Hilbert transform to get imaginary and real part of the signal ,after baseline wandering of the given input signal. Then finding the thresholding factor of the first derivative of the Hilbert transform, later getting the result as R peak in the signal. It shows 96.3% accuracy for the given signal[24]

M.B.I.Hasan (2014), In this paper, author shows a new method to detect R peak interval from complex QRS interval using zero crossing method to detect the peak shifting from negative slope to positive slope and hence detecting it as R peak in that complex interval .if any error occur in the sample position then they apply local maxima to find the accurate peak , showing 98% accurate result in sensitivity of signal[25].

R.wall.w (2012), In this paper, author proposed many different methods to detect the zero crossing line or slope of any peak or signal, making rest part zero and counting the peaks going from negative points to positive points only.

It can be detected using integration method or op-pam method using hardware device or signum function or finding first derivative of the signal and then applying threshold level[26].

Mayer .m (2009), In this paper, author deals with the complex method to detect the "R" peak from complex QRS interval using pan-Tompkins and wavelet transform finding its haar transform the distinguishing the signal part and the noise part and then applying transform for 'n1' level to get the require peak and then applying threshold to get QRS complex and then find out the derivative and get "RR" peak form that given input signal[27].

CHAPTER 3

PROBLEM STATEMENT

3.1 Problem Formulation

Biomedical signal processing is a that domain which deals with the signal processing of not only random or periodic digital signal but also with different biomedical signals whose results are used in development of any medical information and methods for detection and cure of different disease. It also helps to detect the particular disease easily, while sitting at home, now a day's HRV analysis is playing role in detection of R peak in the ECG signal which tells a lot about the specific information regarding pumping of heart, heartbeat, its occurrence time interval per second.

As it is seen that there are 'N' numbers of the methods that are and can be used to detect the 'R' peak and 'RR' peak interval from any desired or standard ECG signal, traditional methods shows 80% accuracy in sensitivity of signal, to find the sharp and correct location of the 'R' peak in the signal but they do not tell the other specific information like the is noise is removed or not ?from the signal? And how much noise is present in the signal, is it periodic now or not, regularity and flu caution in the signal , as it is very important to have desired ECG signal [1].

Hence, it will give false results as wrong information and values of the false negative and false positive peaks in the outcome. This can effect the sensitivity and specificity of the signal, and do not shows accurate location of the R peak in the results. It do not calculate the randomness and fluctuation of the signal. It will be no more useable so to overcome these demerits, 'ApEn' is introduced using particular 'r' threshold value to filter the not usable and noisy contents from the signal. This method will find R peak by calculating its change in its value i.e sudden change in the QRS complex using ApEn and hence detects R peak.

3.2 Objective Of Study

The objective of study of R peak Detection and HRV analysis in biomedical signal processing is explained below:

a) To study existing techniques of 'R' peak Detection.

b) To detect ' R ' peak using entropy based methods like approximate entropy.

c) To compare and analyze the ' R ' peak detection using ApEn based on different signals.

d) To study the effect of threshold parameter that is ' r ' in R peak detection and analysis.

e) To study the sensitivity and specificity of the given ECG signal.

3.3 SCOPE OF THE STUDY

The scope of this work includes the implementation in R peak detection using information theory based methods like approximate entropy. The sensitivity and specificity will be empathize and improvement in the same will be done and compared with existing methods and also effect of threshold variable ' r ' is analyze. The results are compared with different values of ' r '.This work will help in future use , by giving low error rate and fluctuation in the desired peaks.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

There are a 'N' number of methods to find the 'R' peak in any standard or random ECG signal using different techniques with effective results. But still they are not accurate up to some extent while dealing with sensitivity and specificity. They show 98.1% accuracy but do not deal with the error rate of the signal. So according to problem formulation, the latest and effective method of detection of 'R' peak is calculating its randomness (sudden change in values), for this entropy method is best and gives accurate results by calculating the sudden change in the signal. There are many entropy methods such as i.e. approximate entropy and sample entropy [4].

Approximate entropy is defined as the method in which we calculate the randomness of the signal and the irregularities and the unpredicted values of the fluctuation in the signal, in time domain. It calculates the each and every change in the signal i.e. minute change in the signal.

4.2 Research methodology:

Steps to be followed in research methodology are below:

Step 1: A desired ECG waveform is taken as input signal. In this, 20 different signals are taken which are downloaded from Physionet Bank ATM, of different samples from 5000 to 158000 with different time duration from 10 second to 1 hour sampled signal.

Step 2: Signal is passed from the filter to remove unwanted noise or dc component from it.

Step 3: Short time sampling on the samples of ECG signal are applied and a particular range of samples is selected. Windowing method is applied on the signal, to make small frame size of the taken ECG samples, windowing is done to get each sample of the signal at every point. mostly small size window size is taken as it will helps to detect single peak in single frame otherwise, large window size will cause missing of many peaks in single frame and a very small window size will cause overlapping of the peaks in single frame.

Step 4: Approximate entropy is applied on those samples, calculating the approximate value of each sample in that range. Approximate entropy is applied on each window frame and hence we get entropy of each and every sample in the different frames of the signal. ApEn results in the very small value showing the regularity and predicted samples of the signal, if the value of ApEn is very large it shows that there is still fluctuation in the signal and still randomness is not removed and periodic signal is not received as main output.

It will formulate a single peak in single frames which represent the highest peak having highest entropy value among other peaks in that particular frame only; hence we will get entropy values of the signal.

Step 5: Interpolation is applied on entropy signal, to up sample the signal back to its original signal value as output of ApEn are not in same number of the original signal.

Step 6: Hilbert transform is applied on the signal, to get 90° phase lag, to get imaginary and real values of the signal. Now result will be in imaginary and real part of the signal, later only imaginary part will be selected and next steps are applied on it.

Step 7: Zero crossing detector is used to detect the change of slope in signal from negative to positive value and mark it with star. We will calculated the zero crossing points in the signal i.e. changes of the values from positive to negative and negative to positive respectively. Now we will check this using signum function which helps to check slope of every peak, now, neglecting the first positive to negative change in value will result in suppression of peak which is represented as Q peak. So by calculating the negative to positive change in values we will get peaks near or equal to the original signal, but some time we will get peaks near the original signal.

Step 8: using local maxima, minima, we find out the accurate location of the peak, R peak is detected**.** These are due to some noise , which are being left in the signal, we will later apply local maxima and local minima to calculate the accurate value of the peak present in the signal. 'R' peaks are detected.

Step 9: Now, True Positive (Tp), True Negative (Tn), False Positive (Fp), False Negative (Fn), is calculated for finding the values of specificity and sensitivity of the signal**.** True

Positive is define as the total number of actual peaks present in that signal. True negative is defined as the sum of number of actual peaks and extra peak present in the signal. False Positive is defined as the number of the peaks not detected but present, False Negative is defined as peak detected where peak is present.

Hence Sensitivity is define as number of true positive divided by sum of true positive and false negative and Specificity is define as number of true negative divided by sum of true negative and false positive. Also Sensitivity is defined as how sensitive is the R peak in the output with the real time data and Specificity is define as the how specific it shows the data and results accurate

$$\textbf{Sensitivity} = \frac{\mathbf{tp}}{\mathbf{(tp+fn)}} \qquad (4.1)$$

$$\textbf{Specificity} = \frac{\mathbf{tn}}{\mathbf{(tn+fp)}} \qquad (4.2)$$

$$\textbf{Accuracy} = \frac{\mathbf{(tp+tn)}}{\mathbf{(tp+tn+fn+fp)}} \qquad (4.3)$$

When R peak is detected , if large time error occur then it is removed by changing ‘ r ’ factor value again and again , then those results are compare with existing previous methods.

This will improve the results more by taking the threshold value like a band pass filter value in which only particular level values are passed, neither less nor greater values are stored, this will improve the efficiency and also do not result in zero diagonal matrix. Later, we will find the accurate value of ‘r’ factor and then calculate the entropies of different signal and plot the sensitivity and specificity for that signal and calculate the change in the signal.

Now, improvement is made by selecting the specific values of the variable ‘ r ’ so as to get accurate results with less true false detection and true false detection , sensitivity and specificity. There are other types of entropies also which shows same results like sample entropy, only difference occurs at the last step, in ApEn we take logarithm of X1 and X2 matrix before their difference result but in sample entropy we take first main difference of both matrix and then take logarithm of the final single output to take the specific, absolute value of the final results, but ApEn shows more accurate results than all other entropies

outcomes even many other types of entropies are fail to find the similarities and appropriate difference between the sequences given by user or any other research for future use.

Basically simple entropy can calculate the values of predicted sample but it do not provide desired response as it do not tell the value of little change in the sequences or series, so regularity was important to be calculated to check the minute change in the series, which is not affected by the noise or any other error signal. It practically checks the regularity of signal, which is not possible for the simple entropy algorithms.

CHAPTER 5

SIMULATION RESULTS AND DISCUSSION

5.1 Introduction

In this section, the simulation results of the above mentioned and proposed techniques are obtained and have been discussed. The simulation result has been implemented in MATLAB software version 7.10.0.499 (R2010a). This methodology is results in the sharp and accurate R peak detection by removing the randomness and fluctuation of the signal. It also makes an advantage by low demand of computation of the signal. This will help in HRV analysis by giving low time error and delay in the output, is obtained with the removal of false true detection peaks and true false detection peaks and more specific results with real time data and less large time error [1][11].

5.2 Simulation Results

This method is showing results for very small samples and can be used to apply in real time; output will be very less effected by any random noise. ApEn shows results, which are having very small value in terms of regularities in the signal but if the noise is not removed by the specific threshold or filtered level then ApEn having large value as output will tell us about the noise level and which noise is present, at which place it is present and what is the true or accurate or specific information present in the signal. Approximate entropy is very useful to divide the respected or provided ECG into various parts to detect the different classes of the diseases like epilepsy, any other addiction or schizophrenia. These all steps of ApEn will be coded on MATLAB software to get desired output [2][3][4][6].

Here, Implementation is done by taking random ECG signals, in this input ECG signal have 75000 samples, is downloaded from Physio.net ATM, a MIT based ECG signal with noise .

A) First input ECG signal is shown in Figure 5.1

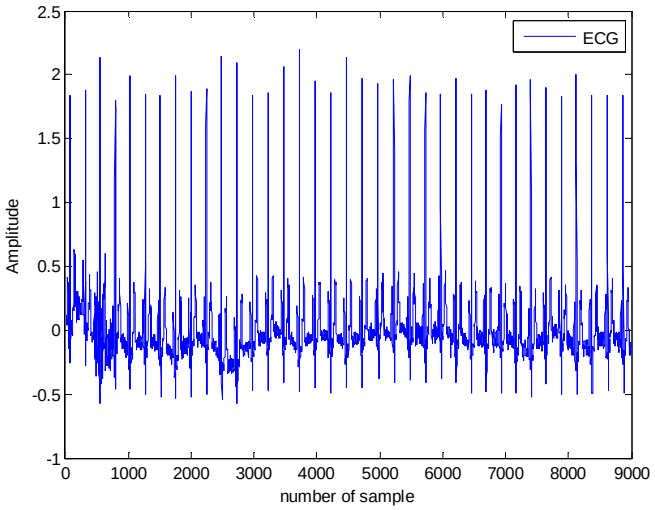

Figure 5.1: Input ECG signal

B) After filtering the ECG signal, Apen (showing 298 values of Apen) of the signal on 9000 samples (short time range selected from large number of samples) is calculated and as shown in Figure 5.2

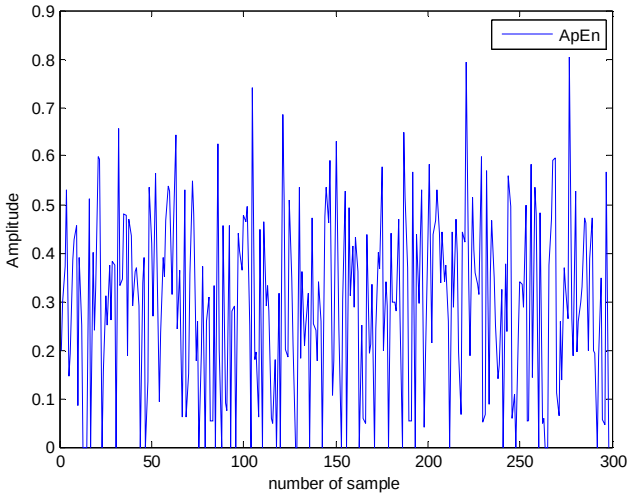

Figure 5.2 : Apen value of signal

C) Now after calculation of Entropy of signal, interpolation of the signal done as shown in Figure 5.3

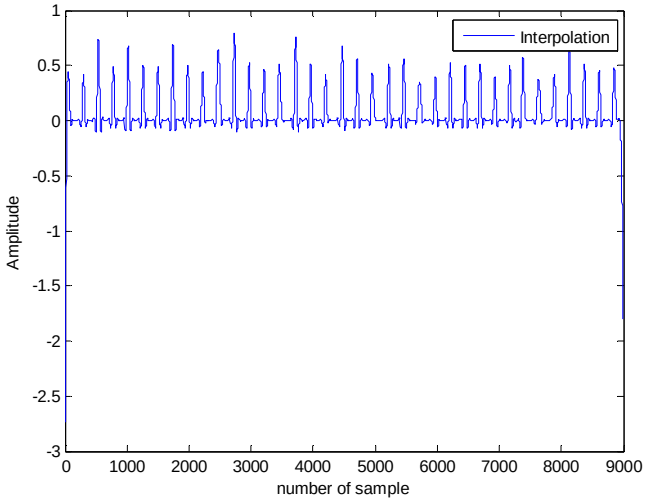

Figure 5.3 : Interpolation of signal

D) Figure 5.4 shows the output of the Hilbert transform

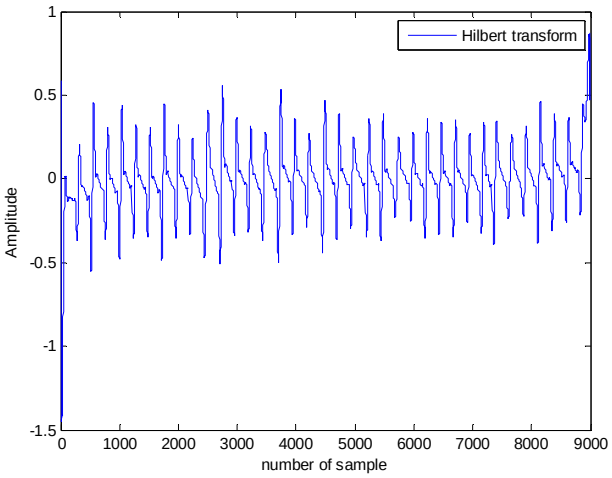

Figure 5.4: Hilbert transform of signal

E) now the final outcome , “R” peaks are shown in the figure 5.5 with 99.98 % sensitivity and 99.1 % specificity of the signal.

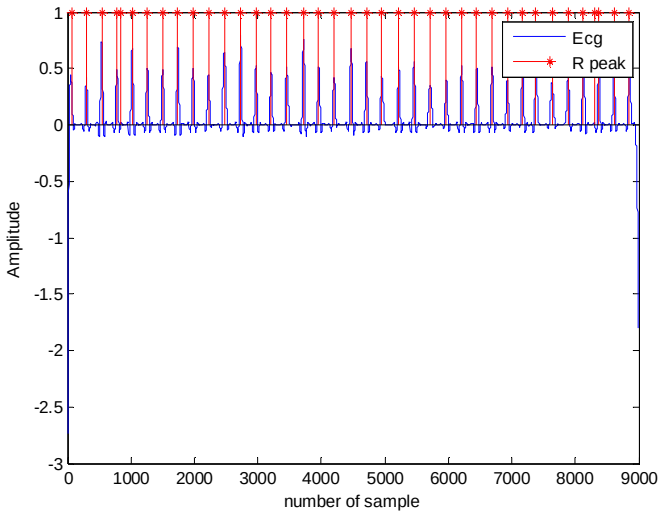

Figure 5.5: ‘R’ peak of the signal

F) now Figure 5.6 shows the plot of different values of ‘r’ factor with respect to the ApEn values of the 5 signal.

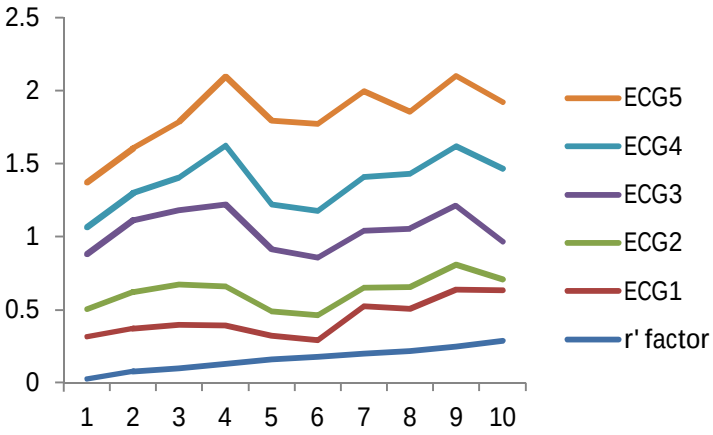

Figure 5.6: Apen v/s ‘r’ factor

G) Now Figure 5.7 shows the plot of ‘r’ factor with respect to the sensitivity and specificity values of the 5 signal.

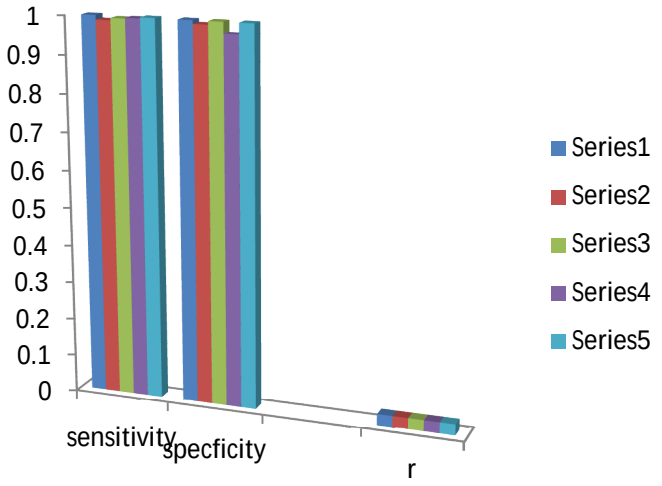

Figure 5.7: ‘r’ v/s sensitivity and specificity

H) Now Figure 5.8 shows the table 5.1 of ‘r’ factor with respect to the sensitivity and specificity values of the 5 signal.

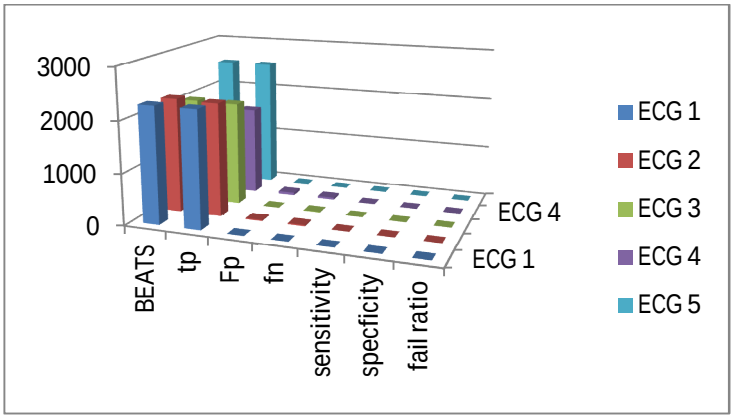

Figure 5.8: ECG signal and their parameters

I) Now Table 5.1 shows the values of ApEn of the 5 different signals with respect to different ‘r’ factor.

Table 5.1: ApEn v/s ‘r’ factor

r' factor	ECG1	ECG2	ECG3	ECG4	ECG5
0.03	0.289	0.1872	0.3748	0.1861	0.3036
0.08	0.2921	0.2511	0.4895	0.1864	0.306
0.1	0.2999	0.2728	0.5109	0.2206	0.3803
0.13	0.2631	0.2659	0.5604	0.4022	0.4762
0.16	0.1642	0.1654	0.4238	0.3065	0.5753
0.18	0.1115	0.1738	0.3942	0.3169	0.5961
0.2	0.32694	0.1239	0.3901	0.3668	0.5887
0.22	0.2873	0.1486	0.3986	0.375	0.4251
0.25	0.3904	0.17	0.4003	0.4107	0.4791
0.29	0.3442	0.0746	0.2602	0.4984	0.4531

J) Now Table 5.2 shows the values tp, fp, fn, sensitivity and specificity of the different signal taken.

Table 5.2: Parameters of ECG signal

ECG signal	BEATS	Tp	fp	Fn	Sensitivity	specificity	fail ratio
ECG 1	2273	2273	0	0	1	1	0
ECG 2	2229	2205	21	24	0.989	0.991	0.02
ECG 3	2027	2016	1	11	0.995	1	0.006
ECG 4	1763	1722	53	41	0.997	0.97	0.053
ECG 5	2532	2531	0	1	1	1	0
				AVERAGE	0.9989	0.9922	0.02

K) Now table 5.3 shows the value of tp, fp, fn, sensitivity and specificity of the different signal taken

Table 5.3: Parameters of ECG signal

File(ECG)	Beats	tp	fn	fp	sens	spec	fail ratio
1	2987	2980	1	7	0.96	0.96	0
2	1863	1862	0	1	0.99	0.98	0.1
3	1619	1618	0	1	0.991	0.99	0.01
4	2601	2600	1	1	0.991	1	0.01
5	2273	2273	0	0	1	0.97	0.03
6	1865	1863	8	2	0.98	0.95	0.01
7	2187	2186	6	1	0.99	0.92	0.06
8	2084	2084	1	0	1	0.96	0.04
9	2219	2205	5	14	0.97	1	0.03
10	2579	2569	1	10	0.97	0.92	0.06
11	2027	2017	2	10	0.94	0.87	0.11
12	2137	2131	3	6	0.96	1	0.04
13	1763	1722	0	43	0.95	0.922	0.03
14	2532	2531	2	1	0.99	1	0.1
15	1795	1791	2	4	0.98	0.97	0.1
16	1080	1079	0	1	0.99	0.977	0.2
17	1953	1953	2	0	1	1	0
19	2412	2411	3	1	0.99	1	0.1
20	1524	1522	0	2	0.98	0.94	0.4
				Average	0.9976	0.978	

L) Tabel 5.4 shows mean v/s ‘r’ factor

Table 5.4 : mean v/s ‘r’ factor

r' factor	ECG1	ECG2	ECG3	ECG4	ECG5	Mean
0.03	0.289	0.1872	0.3748	0.1861	0.3036	0.26814
0.08	0.2921	0.2511	0.4895	0.1864	0.306	0.30502
0.1	0.2999	0.2728	0.5109	0.2206	0.3803	0.3369
0.13	0.2631	0.2659	0.5604	0.4022	0.4762	0.39356
0.16	0.1642	0.1654	0.4238	0.3065	0.5753	0.32704
0.18	0.1115	0.1738	0.3942	0.3169	0.5961	0.3185
0.2	0.32694	0.1239	0.3901	0.3668	0.5887	0.359288
0.22	0.2873	0.1486	0.3986	0.375	0.4251	0.32692
0.25	0.3904	0.17	0.4003	0.4107	0.4791	0.3701
0.29	0.3442	0.0746	0.2602	0.4984	0.4531	0.3261

Now, these all signal shows their respective result first according to same ‘r’ factor and secondly, according to different ‘r’ factor effecting their Apen values and sensitivity and specificity . It shows a change in apen values first increase with increase in ‘r’ factor up to r=0.16 then sudden decrease in Apen value in increasing ‘r’ from 0.16 to 0.2 values . it shows an average value of 0.998 or 99.8 % sensitivity and 0.9922 or 99.22% specificity of the all 5 different random ECG signal and showing only 0.02 or only 2% error in the detection of the peak, hence better than old methods which show 97% accuracy but this method shows 99.9% accuracy . There are two tables which defines the apen values with respect to different ‘r’ factor and tp,fn,fp values of those signal showing sensitivity and specificity of the signal.

CHAPTER 6

SUMMARY AND CONCLUSION

This report describes the various entropy approaches to analyze heart rate variability and R peak detection which are quite efficient for short and noisy data series specially confronted in heart signals and other biological ones. These models compare data sample with their own sets and also with other set of samples and hence tried to draw inferences regarding efficiency and accuracy of these models on analysis of heart rate variability and R peak. Main focus of our present work is to study effect of threshold factor 'r' on approximate entropy of random ECG signal and R peak detection, this will result in 99.89% accuracy in term sensitivity and specificity, with less detection error rate i.e. 0.02% and time delay error.

ApEn values of all the random ECG signal shows, first increase in the ApEn value with increase in the threshold factor 'r' and again increase in 'r' factor value it shows decrease in ApEn values of the signal. Due to first derivative of the signal, it shows some error in peak location. It is shifted by 2 sample or delayed by 2 samples, these occur due to some noise left in ECG signal. This problem is overcome by maxima and minima values of the input ECG signal and detected peak of the signal. It shows accurate results by showing more randomness in mean of the signals than any other existing methods.

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