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Cardiac Health Status Implementation on Mobile Phone

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Abstract**—**ECG is a bio-medical signal which records the heart's electrical signal versus time. It is an important diagnosis tool for assessing heart's functions. In this paper we discuss the methods of feature extraction of ECG signals, both statistical and morphological who play a significant role in diagnosing most of the cardiac diseases. A mobile application is developed which extracts features of ECG signal like RR interval, QRS wave, SDNN etc. in real- time and use these features for diagnosing whether a patient suffers from different 8 types of arrhythmia. The model is embedded with a decision support system formed offline by learning the behavior of the signals of various patients suffering from arrhythmia.

Keywords**—**Data Mining, ECG analysis, Feature Extraction, Pattern Recognition, Signal processing

I. Introduction

ACCORDING to WHOs report of September 2011 Cardiovascular Diseases (CVDs) are the number one cause of death globally: more people die annually from CVDs than from any other cause. An estimated 17.3 million people died from CVDs in 2008, representing 30% of all global deaths. Of these deaths, an estimated 7.3 million were due to coronary heart disease and 6.2 million were due to stroke. Low- and middle-income countries are disproportionally affected: over 80% of CVD deaths take place in low- and middle-income countries and occur almost equally in men and women. These are projected to remain the single leading causes of death. If these abnormal symptoms can be early detected and diagnosed, time is saved to prevent the occurrence of heart attack or to provide an efficient treatment in time. Therefore, to reduce the number of disabilities and deaths caused by heart attack, it is necessary to have an effective method for early detection and early treatment. Hence, it is necessary to develop a portable hand held cardiac surveillance system to provide long-time continuous cardiac monitoring service.

The system should be cost effective, risk-free and easy to use in everyday life. This paper discusses design of the Mobile cardiac monitoring system [11] which we have developed and specifies some interesting technical details related to simple and efficient way of extracting features of ECG signals [1] for disease prediction. The ECG signal and its important morphological features are shown in figure 1. Each feature has significance and depicts the health of heart. Hence it is important to extract these features very accurately to diagnose the disease. The *'cardiac health status implementation on mobile phone'* paper is organized as follows:

In section 2, the paper gives an insight of the signal pre-processing technique required to remove noise from the ECG signal. Section 3 presents the feature extraction scheme used to extract important features of the ECG signal. Further section 4 performs the classification of the extracted features and the calculation of heart rate (HBR). Finally in section 5, the conclusion and future enhancement in this field are described.

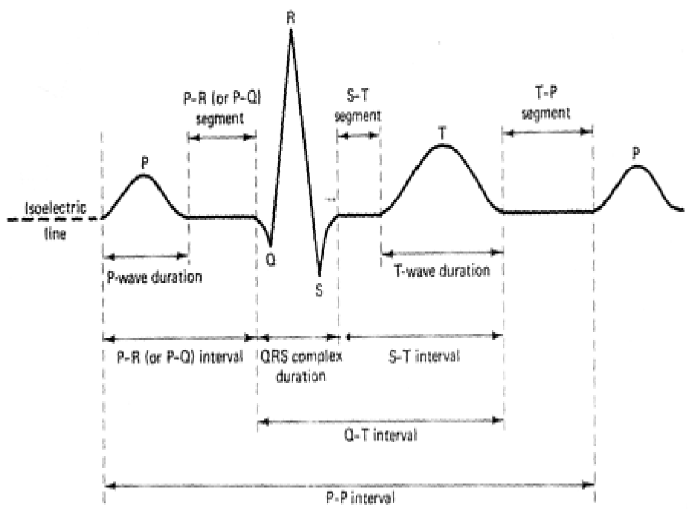

Fig 1: ECG signal

II. ECG Signal Classification [5]

In the recent years, the task of automated analysis of ECG waves has been broken down in parts namely:

(i) Signal Pre-processing
(ii) QRS-detection
(iii) Feature Extraction
(iv) Signal Classification.

Each process is assigned a given task and must be processed in a sequential manner, thus input for one block is the output of the previous block. Various techniques have been worked on for each block which yields accurate results. This paper would be focusing on QRS detection and Feature extraction techniques which would be efficient, robust yet light weighted to be implemented on PDA's. This is because QRS is an important part which relates to most of disease related problems. Figure 2 shows the basic steps in ECG classification process.

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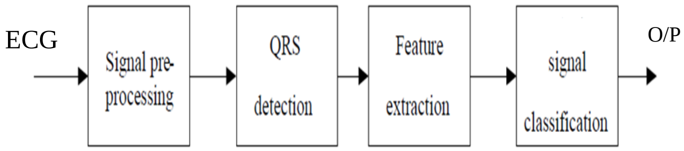

Figure 2: Steps in ECG Classification

III. SIGNAL PRE-PROCESSING

The ECG signals used for experimentation are taken from the MIT-BIH Arrhythmia database [2]. These ECG signals are digitized through sampling at 360 samples/s, quantized, and encoded with 11 bits.

This database provides standard input ECG values. However, the input may contain noise generated from factors like patient movement, electrode contact noise, instrumentation noise, muscular activity and baseline wandering etc. The snapshot of the raw signal directly plotted is seen in figure 3. The main purpose of signal pre-processing is:

(i) To remove unwanted signal component that are corrupting the signal of interest

(ii) To extract information from the acquired signal.

For this purpose in this work High pass filter (HPF) is used to remove noise. HPF mainly reduces the false detection caused by various types of interferences present in ECG signals. This filter also helps to remove baseline drift.

The following equation 1 is used to simulate the effect of high pass filter on a series of digital signals:

$$y[i] := \alpha * (y[i-1] + x[i] - x[i-1]) \quad \ldots.. \qquad (1)$$
$(i=1 \ldots n)$

where x=time values,
y=voltage values and
α=cutoff frequency.

Fig 3: Noise affected ECG signal

Figure 4 shows the input ECG signal after noise removal, where baseline drift, unwanted spikes are removed and signal is normalized.

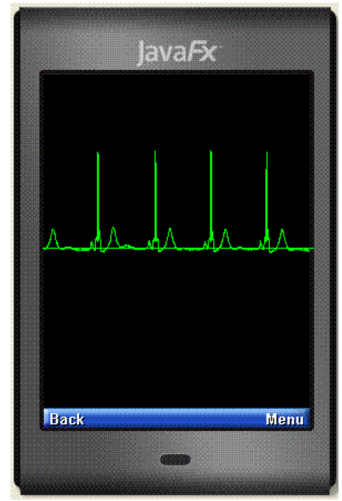

Fig 4 ECG signal after applying HPF

IV. FEATURE EXTRACTION

The majority of clinically useful information in the ECG is originated in the intervals and amplitude defined by its features. The deviation in normal electrical patterns indicates various cardiac disorders. Therefore it is necessary to design the accurate feature extraction system.

A. R-R interval and P, Q, R, S, T points.

The P, Q, R, S and T points denote different patterns of a normal ECG graph. Detection of ECG RR interval from the recorded ECG signal is crucial for a sustainable health monitoring scenario, since a wide range of heart diseases like tachycardia, Arrhythmia; palpitations etc. can be efficiently diagnosed utilizing the resultant RR interval. By knowing the RR peak, it is easy to further calculate the Heart Beat Rate (HBR). Average threshold method is been selected for RR detection, and tested it on an emulator mobile phone. Results of figure 5 depicts detected P,Q,R,S,T points from the input wave. Here we have applied logic of pattern matching. For example the R point is detected where highest amplitude is detected in particular ECG interval. The average threshold over no. of intervals is calculated first and then each point of wave is compared with this average amplitude. The amplitude is calculated over moving window to update the threshold values.

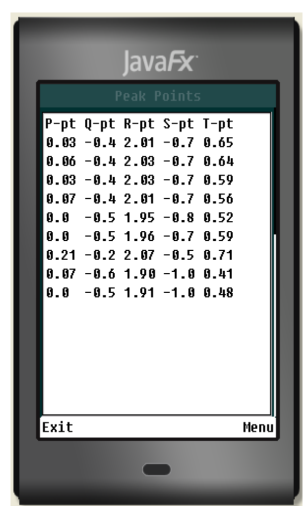

Fig 5: Detected P,Q,R,S,T wave

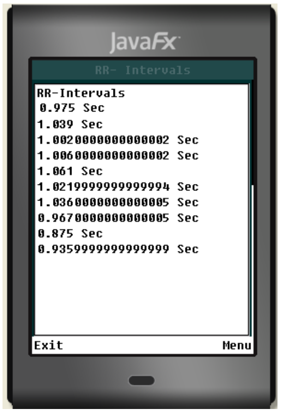

Fig7. Detected. R-R interval

The table in figure 6 shows the R-R interval along with a comparison with the physionet [2] values.

t0	b0	RR (sec)	b1	t1
0:00.000	[0]	0.975	N	0:00.975
0:00.975	N	1.036	N	0:02.011
0:02.011	N	1.006	N	0:03.017
0:03.017	N	1.006	N	0:04.022
0:04.022	N	1.058	N	0:05.081
0:05.081	N	1.022	N	0:06.103
0:06.103	N	1.039	N	0:07.142
0:07.142	N	0.964	N	0:08.106
0:08.106	N	0.878	N	0:08.983
0:08.983	N	0.936	N	0:09.919

Fig 6. R-R interval from Physionet

B. QRS complex and other Intervals

The QRS complex is the most striking waveform within the ECG. Since it reflects the electrical activity within the heart during the vascular contraction, the time of occurrence and its shape provide much about the current state of the heart.

There are large numbers of QRS detection schemes that have been developed over time. Among them the Pan Tompkins is the most effective which has been used in this experiment [10].

The first step of filtering the signal has already been specified in section 2.

Differentiation

In order to get the QRS complex slope information the signal is differentiated by using the following difference equation:-

$$y(nT) = \left(\frac{1}{8T}\right)[-x(nT-2T) - 2x(nT-T) + 2x(nT+T) + x(nT+2T)] \quad \ldots(2)$$

Squaring function

The differentiated signal is squared in order to make all the data points' positive and to make non-linear amplification of the output of the higher derivative.

The following equation was applied:-

$$y(nT) = [x(nT)]^2 \quad \ldots(3)$$

Moving window integrator

The purpose of moving window integrator is to obtain the feature information in addition to the slope of the R wave. The number of samples in the moving window integrator is important the width of the window is determined empirically. The window size was chosen to be 30 samples wide.

It is calculated as follows:-

$$y(nT) = \left(\frac{1}{N}\right)[x(nT-(N-1)T) + x(nT-(N-2)T) + \cdots + x(nT)] \quad \ldots(4)$$

As soon as the QRS wave is detected the corresponding segments and intervals can also be extracted as follows interval detection are as follows:-

(i) PR interval

It starts with the onset of P wave and ends at the onset of the q wave

(ii) ST segment

It starts with the offset of S wave to onset of t wave.

(iii) QT interval

It begins at the onset of the Q wave and ends at the offset of T wave

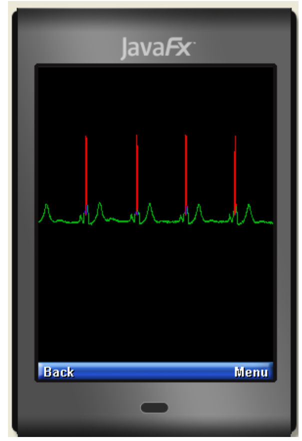

Fig 7 Detected QRS complex result

V. SIGNAL CLASSIFICATION

Signal classification is comparing the extracted values with the expert rules.

Eight different types of Arrhythmia [4] considered in this work :

(i) Left bundle branch block (LBBB).
(ii) Normal sinus rhythm (NSR).
(iii) Pre-ventricular contraction (PVC).
(iv) Atrial fibrillation (AF).
(v) Ventricular fibrillation (VF).
(vi) Complete heart block (CHB).
(vii) Ischemic dilated Cardiomyopathy (ISCH).
(viii) Sick sinus syndrome (SSS).

In this work time domain analysis method for R-R intervals [12] is implemented. Also for classification of Arrhythmia statistical features of ECG signals are considered. These features are listed below[4]:

i) Standard deviation of NN intervals (SDNN).
ii) Standard deviation of difference between adjacent NN intervals (SDSD).
iii) Root mean square successive difference of intervals which are extracted from heart rate signals (RMSSD).
iv) The proportion derived by dividing nn50 by total number of NN intervals (pNN50).

The classification phase is done using two different ways[8]. First way is to compare extracted features with standard rules specified by domain experts in order to identify whether patient is suffering from any cardiac disease.

The second way is adding intelligence while classifying the signal with the help of data mining algorithms. Here, first the statistical features mentioned earlier are extracted from signals of different Arrhythmia suffering patients and then grouped in 8 different clusters of Arrhythmia. Well known K-Means [14] algorithm is used to cluster these values. K Means is simple portioned algorithm can be used for clustering large dataset on predefined attributes.

Algorithm k-means

1. Decide on a value for k.
2. Initialize the k cluster centers (randomly, if necessary).

3. Decide the class memberships of the N objects by assigning them to the nearest cluster center.
4. Re-estimate the k cluster centers, by assuming the memberships found above are correct.
5. If none of the N objects changed membership in the last iteration, exit. Otherwise go to step 3.

The formed rule base with the help of clustering algorithm is then used for classification of the live signals in different types of Arrhythmia.

VI. RESULTS AND DISCUSSION

The input signals are taken from MITBIH Arrhythmia database. Snapshots of results of wave detection and arrhythmia classification are shown in figure 7 and 8.
The accuracy of the intelligent model built with the help of data mining algorithm is better than the analytical model as the ranges of the disease are self learned from huge sample of database. The accuracy of analytical model in which only values are compared with the tabulated ranges is 67% whereas the accuracy of the intelligent model comes out to be 87%.

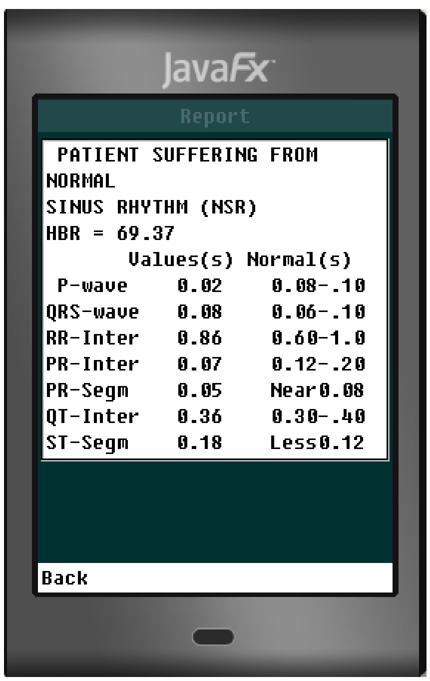

Fig. 8 Classification of ECG

VII. TECHNOLOGICAL OVERVIEW

For experimental purpose the work is implemented for SYMBIAN operating system in J2ME.
The key features of our system are:
(i) Software works on SYMBIAN/JAVA mobile phone
(ii) It implements accurate and high efficiency algorithm.
(iii) The system is user friendly and portable.
(iv) Able to classify signals in 8 types of arrhythmia in real time on mobile.
This system can be used with WBAN (Wireless Body Area Network) where sensors are deployed on human body. The bio-signals like ECG are captured and transferred on mobile as an input to developed system and real time cardiac health status evaluation is possible.

VI. CONCLUSION

The proposed and developed system performs analysis of various ECG signals and evaluates persons risk level i.e. health condition. The system is developed in such a way so as to handle normal as well as abnormal cardiac conditions. The extracted features are compared with the expert rules which further help in determining the risk level of the patient. The patient as well as the doctor will be at ease as the device is portable and handy.
Future development of the system will explore the co-relation among medical data to reduce the false positive rate. The system may be applied to various other medical fields for the welfare of the community.

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