Real Time Analysis and Diagnosis of ECG Signal for Tachycardia Condition

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ABSTRACT
With heart diseases, and associated complications, being one of the major causes of death around the world, and in spite of decreased mortality rate, detection of irregularities in the rhythms of the heart is a growing field in medical research. Extended patient monitoring during normal activity has become increasingly important as a standard preventive cardiological procedure for detection of cardiac conditions. This paper presents a development platform for portable real-time analysis of ECG signals which can be used as an advanced warning device, using android based mobile phone. This paper briefly discusses an ECG data capture unit, with an emphasis on the software for analyzing the ECG signals, and the algorithm of analyzing and detecting cardiac conditions for 'Tachycardia' type – the most common kind of cardiac abnormality.

General Terms
Digital signal Processing, Tachycardia, Biomedical signal Processing.

Keywords
mHealth, eHealth, Telemedicine, Telemetry, Android, Smartphone, ECG.

1. INTRODUCTION
According to the World Health Organization, Heart disease or cardiovascular diseases (CVD) are the number one cause of death worldwide. Of these deaths, 82% take place in low- and middle-income countries. Given their computing power and pervasiveness, it is possible for mobile phones to aid in the delivery of quality health care, particularly to rural populations distant from physicians with the expertise needed to diagnose CVD.

Advances in mobile phone technology have resulted in global availability of portable computing devices capable of performing many of the functions traditionally requiring desktop and larger computers. In addition to their technological features, mobile phones have a large cultural impact. They are user-friendly and are among the most efficient and most widely used means of communication. Currently there is about one cell phone for every two humans in the world.

The estimated cost of direct and indirect treatment of cardiovascular diseases in the United States alone is $475.3 billion for 2009 according to American Heart Association [2]. To reduce these costs and the anxiety of people with known cardiovascular problems we propose a portable monitoring system that monitors the heart and notifies the person or external party in case of abnormalities. Our monitoring system is meant for patients that have a known cardiovascular disease that need to be monitored continuously.

Traditional heart monitoring solutions exist for many years such as the Holter monitor which records the patient's ECG for 24 or 48 hours and is then analyzed afterwards by the cardiologist. The patient can wear the device and go home and resume his/her normal activities. The main drawback of such monitoring solutions is due to unavailability of help if a major incident occurs during the monitoring phase. It is recorded but no immediate action is taken to help the user. Later seeing the records may not be of any use to the patient. So we are proposing a system that will measure the ECG of a patient continuously on real time basis and analyses it within the mobile phone itself, and will gives the patient general information about their health. We can also store this information for further use and reference.

The analysis software can be used to diagnose the various cardiac conditions of the patient as well as other heart related signals, e.g. pulse rate. The Tachycardia heart condition is a common form of cardiac disease caused by fluctuations in the QRS complex of the cardiac rhythm [7].

Figure 1 depicts the overall structure of the proposed system and patient/doctor communication links of the ECG system. This paper reports several components of the system, which are currently functional and prototyped.

2. ARCHITECTURE
Now as the technology is advanced, real time signal processing is possible, with inbuilt smart phone sensors and using Android as an operating system for platform development. The smart phone processes the data and monitors the patient's wellbeing, and in case of an emergency, it can automatically inform the concern physician.

Fig. 1: Architecture of Proposed System

The ECG monitoring device has two major components: the software component and the hardware component. Shown in Figure 1, the ECG Analysis Software component is an integral part of the ECG device since the software performs analysis on the filtered, amplified, and digitized signal, while streaming from the patient in real-time. In our system, the patient is connected to the ECG sensor unit directly using a set of commercial, three-lead gel-based sensory probes [3].

Data from sensors is collected and processed in the smart phone, for high risk cardiac patient the ECG signal data needs to be collected continuously and should be processed on the real time basis.

The analysis is currently focused on the diagnosis of Tachycardia, which is based on narrow and wide QRS complexes. The analysis software is able to detect the cutoffs (start and end points) of P-wave and QRS durations as well as the peaks of the waves. These cutoffs are the key for the diagnosis of Tachycardia.

After the R-peak in the QRS complex is detected the heart rate is computed. Depending on the heart rate and determination of any aberrations in the two complexes, a preliminary prognosis of Tachycardia can be deduced to advise the patient at home.

3. REAL TIME QRS DETECTION

The most important of all the waves in the ECG waveform is the QRS complex. The accurate detection of the R-peak of the QRS complex is the prerequisite for the reliable function of ECG-analyzers [4]. The recognition of almost all ECG parameters is based on a fixed point identifiable at each cycle. R-peak is suitable for use as the datum point, because it has the largest amplitude and sharpest waveform that can be extracted from ECG.

The time and amplitude measurements can be performed when the apex of the R-peak is detected at each cycle.

There is a large number of recognition algorithms used in ECG-analyzers and, in many cases, the principles of operation vary. Some are based on different types of amplitude triggering, while others examine the signal in the frequency domain [5, 6]. The adaptive properties of algorithms to the changing signal may differ and some algorithms use statistical methods for identification. We have implemented the Pan-Tompkins real time QRS detection algorithm [1]. As shown in fig. 2 this algorithm uses filtering, differentiation, signal squaring and time averaging to detect the complex.

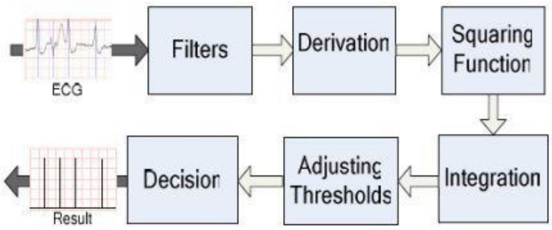

Fig. 2: Pan –Tompkins real time QRS detection Algorithm

3.1 Filtering

ECG signals from the electrodes are corrupted by various sources, such as the 60 Hz power line noise, potentials from muscular activity, and interferences from other nearby electronic devices. Hence, the signals must undergo pre-processing like filtering to remove unwanted data from being processed and misinterpreted.

The band-pass filter is obtained by cascading the 2nd order low-pass filter and the high-pass filter.

3.1.1 Low-pass Filter

The transfer function for 2nd order low pass filter is given by:

$$H(z) = (1 - z^{-6})^2 / (1 - z^{-1})^2$$

$$y[n] = 2\, y[n-1] - y[n-2] + x[n] - 2\, x[n-6] + x[n12]$$

Where the cutoff frequency is about 11 Hz and the gain is 36.

3.1.2 High-pass Filter

The transfer function for the high pass filter is:

$$H(z) = Y(z)/X(z) = (1 + 32\, z^{-16} + z^{-32}) / (1 + z^{-1})$$

The gain for this filter is 32.

3.2 Differentiator

After filtering, the signal is differentiated to provide the QRS complex slope information. We used a five point derivative with transfer function:

$$H(z) = 0.1\, (2 + z^{-1} - z^{-3} - 2\, z^{-4})$$

3.3 Squaring function

After differentiation, the signal is squared point by point. The equation of this operation is

$$y[n] = (x[n])^2$$

This makes all data points positive and does nonlinear amplification of the output of the derivative emphasizing the higher frequencies.

3.4 Moving-Window Integration

The purpose of moving window integration is to obtain waveform feature information in addition to the slope of R wave.

It is calculated from

$$y[n] = (x[n - (N-1)] + x[n - (N-2)] + \ldots + x[n]) / N$$

N is number of samples in the width of an integration window.

3.5 Computation of Heart Rate

After R peak detection in QRS complexes the heart rate is computed in terms of BPM (bits per minute) from no of R peaks detected per minute.

3.6 Results

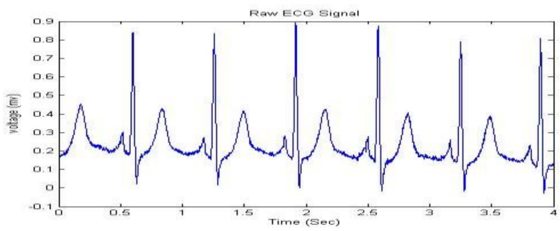

Fig. 3: Raw ECG Signal

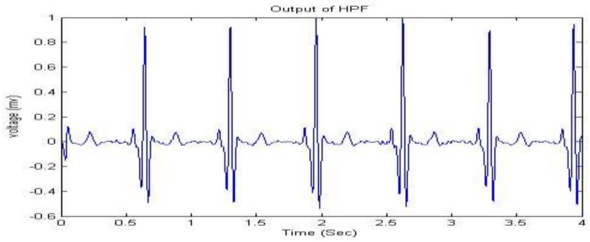

Fig. 4: Output of Bandpass filter

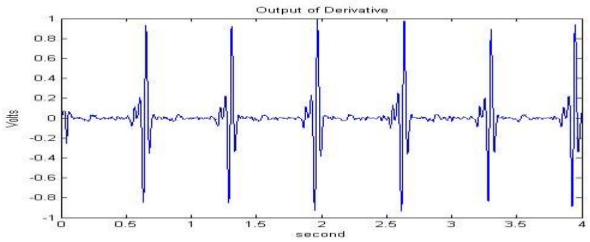

Fig. 5: Output of Differentiator

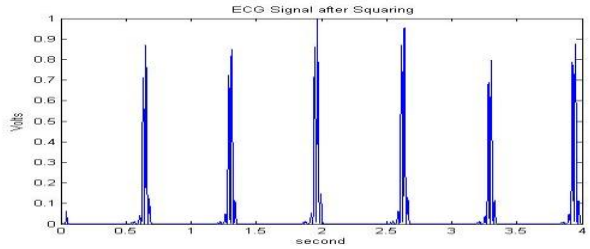

Fig. 6: Output of Squaring Function

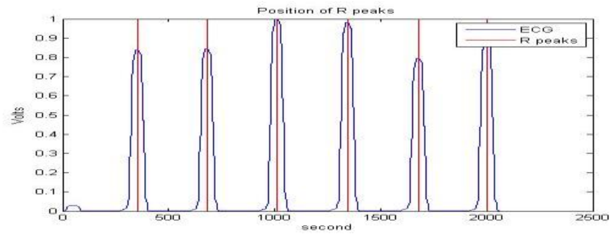

Fig. 7: Output of moving window integrator and detected R-peaks

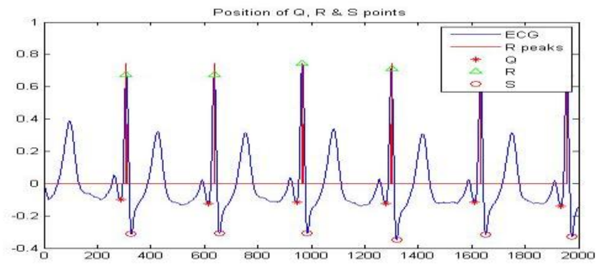

Fig. 8: Position of Q, R & S points in original signal

4. ANALYSIS AND DIAGNOSIS OF TACHYCARDIA

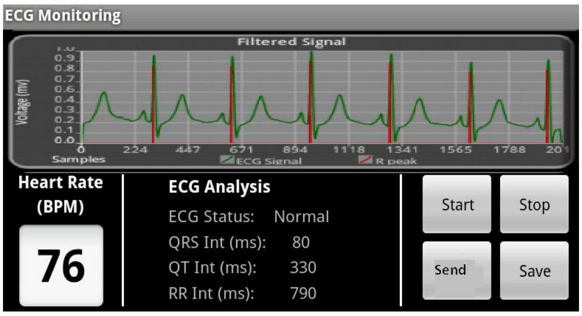

Fig. 9: Output on Android Platform

4.1 Mapping

An important analytical and diagnostic tool is a table or knowledge-base for mapping the stages of blood flow and the associated electrical potentials and (re)polarizations into the segments of the waveform. The variations in the time - intervals that these signals extend (longer, shorter, or just-right), render ECG waveform a diagnostic capability tool. Table 1 is the summary of the knowledge-base data used for diagnosing Tachycardia condition [6].

4.2 An Algorithm for Detecting Tachycardia

Currently our main focus is on the diagnosis of tachycardia based on narrow and wide QRS complexes. We have developed, and implementing, an algorithm for detecting Tachycardia cardiac conditions. The algorithm entails mapping the knowledge-base information that relates the heat rate, the polarities, and the waveform segments of a patient's ECG real-time signal into the corpus of cardiovascular prognosis database. (We are currently implementing the prognosis -component of the interface software (GUI) for advising the patient of the prognosis on a mobile phone Fig. 9) Figure 10 illustrates the algorithm for the Tachycardia detection.

5. CONCLUSION

Detection of irregularities in the rhythms of the heart is a growing field in medical research. The use of an affordable device for monitoring and analyzing ECG signals at home can provide informative details of a patient and simultaneous alert to the doctor of any emergencies. The goal is to develop a platform for portable real-time analysis of ECG signals which can be used as an advanced warning device and provide a capability for real time (software) analysis of ECG signal in the quick response time, to notify the doctor's office.

The ECG data monitoring device is comprised of two major components: the software component and the hardware component. The ECG Analysis Software component is an integral part of the device since the software performs analysis on the filtered, amplified, and digitized signal, obtained from the patient in real-time. The software analysis is currently focused on the diagnosis of Tachycardia, which is based on narrow and wide QRS complexes. The software is able to detect the cutoffs (start and end points) of P wave and QRS durations as well as the peaks of the waves. These cutoffs are the key for the diagnosis of Tachycardia. The informative and user-friendly GUI presents the cardiac patient with different causative and cautionary information relating the heart on a mobile phone (wirelessly), while, at the same time, provides detail information to the doctor's office.

6. FUTURE DEVELOPMENT

The algorithm is able to detect Tachycardia. The next goal is to detect Bradycardia and Premature Ventricular Contraction (PVC) which are heart abnormalities. Bradycardia is the one in which heart beats falls down below 60 beats per minute and in PVC early or premature heart beats gets generated in ventricle of heart.

7. ACKNOWLEDGMENTS

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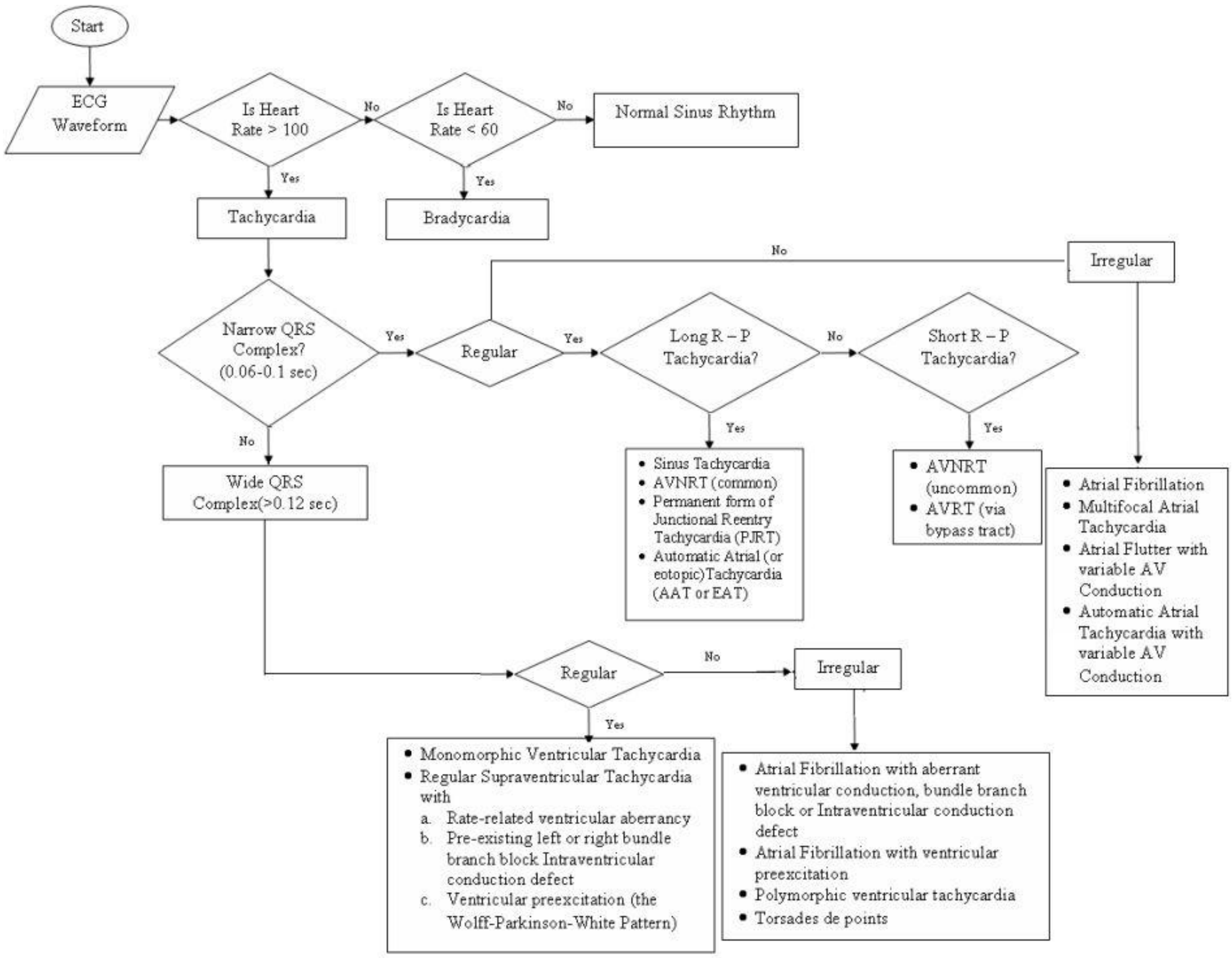

Fig. 10: Algorithm Flowchart

TABLE 1: MAPPING OF WAVEFORMS TO DIFFERENT SECTIONS IN THE HEART

Waveform/Interval Name	**Cause of the Wave**	**Amplitude (y- axis)**	**Time Interval (x-axis)**	**Visual Characteristics of the waveform**
P-wave	Represents atrial depolarization	Normal amplitude is 1-1.5 mm	<0.12 sec	Small, rounded and upright
P-R segment	Indicates the impulse traveling through the AV node, Bundle of High's and Bundle Branches	No amplitude, Should be flat	Not measured	Should be flat
PR interval	Cause of P-wave + Cause of P-R segment	N/A	<0.12 – 0.20 sec	Includes the P wave and the P-R segment
QRS complex	Represents ventricular depolarization	Normal amplitude of R-wave is 8-12 mm	<0.04 - 0.10 sec (QRS interval)	The first negative wave in the complex is the Q wave, the first positive wave in the complex is the R-wave and the first negative wave following the R wave is the S wave
S-T segment	All ventricular muscles depolarized	Should be flat	Not measured	Normally, it should be the same voltage as P-R segment
T wave	Represents ventricular repolarization	Normal amplitude is 2-5mm	Not measured	Polarity same as QRS complex. Usually correlates with the polarity of R wave.
QT interval	Measures depolarization and repolarization time of ventricles	N/A	It varies with heart rate, age and sex. A commonly used correction is corrected QTc (corrected QT) QTc = QT/(square root of RR interval). RR interval = the distance between QRS complexes	Includes the complex, ST segment and T wave
U wave	Purkinje fiber repolarization	Not measured (low voltage)	< 0.01 sec	Usually of low voltage and same polarity as T wave when present