A real time ECG signal processing application for arrhythmia detection on portable devices

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Abstract. Arrhythmia describes the disorders of normal heart rate, which, depending on the case, can even be fatal for a patient with severe history of heart disease. The purpose of this work is to develop an application for heart signal visualization, processing and analysis in Android portable devices e.g. Mobile phones, tablets, etc. The application is able to retrieve the signal initially from a file and at a later stage this signal is processed and analysed within the device so that it can be classified according to the features of the arrhythmia. In the processing and analysing stage, different algorithms are included among them the Moving Average and Pan Tompkins algorithm as well as the use of wavelets, in order to extract features and characteristics. At the final stage, testing is performed by simulating our application in real-time records, using the TCP network protocol for communicating the mobile with a simulated signal source. The classification of ECG beat to be processed is performed by neural networks.

1. Introduction
The electrical signals in a normal heart are produced in the natural pacemaker of the heart known as Sino atrial node (SA node). These electrical signals are transmitted from the atria to the ventricles in a rhythmic manner. What is described with the term of arrhythmia is an abnormality of the heartbeat. Some types of arrhythmias may be completely harmless, whereas, in other cases, they may cause sudden death.

The signal recorded by an electrocardiogram shows a series of waveforms associated with the electrical stimuli that arise during each heartbeat. These waveforms are highlighted by consecutive letters of the English alphabet namely: P, Q, R, S, T and U [1].
The main goal of our work was to design and develop an application for visualizing, processing and analyzing a heart signal and its features in Android portable devices. This work has been divided into two key parts. The first involves the use of arrhythmia data from a file and the second the use of an external source that simulates a real time heartbeat. In both cases, signal processing and analysis are performed with algorithms that help us extract the basic features, in order to classify the heartbeat correctly in the final stage.

2. ECG feature extraction and classification algorithms
Applying complex algorithms to mobile phones is a difficult task. For real-time processing and extraction of features from an ECG waveform, the algorithm must be simple and accurate at the same time [2].

2.1. Pan Tompkins Algorithm
A real-time QRS detection algorithm that satisfies the above requirements is the algorithm proposed by J. Pan and W. J. Tompkins (1985). The implementation of the algorithm was based on [3] and [4].

In the first phase, approximately two seconds are required to initialize the detection thresholds based on the signal and noise peaks detected during the learning process. Two cardiac pulses are required to initiate the two average RR interval values: the first value is the mean of all of the most recent eight RR intervals, while the second one is the average of the most recent eight beats that occurred within the range of 92-116% of the current RR interval average.

The algorithm uses a dual threshold technique to locate the lost beats reducing the false negatives. Thresholds are continuously adjusted to the signal characteristics as they are based on the eight most recent signal and noise peaks, detected in the current processed signals. In case the program does not find a QRS complex in the time corresponding to 166% of the current average RR interval, the maximal peak detected in that time interval between these thresholds is considered to be a possible QRS complex. Thus, a minimum computing time is required for the search back process to detect a missing QRS complex.

Once a valid QRS complex is detected, there is a refractory period of 200ms duration before the next complex can be detected, since QRS complexes cannot occur earlier. This period eliminates the possibility of false detection. When a complex is detected after the end of the refractory period, but within 360ms of the previous complex, it must be determined whether it is a valid complex or a T wave. In this case we consider the highest waveform to be the QRS complex.

![Figure 1: ECG intervals and segments](image-url)
2.2. Wavelets
In order to identify the peaks we used wavelets analysis based on Mallat’s algorithm [5]. Initially, we collected 256 samples from the original signal representing each beat. This beat derives from the result of Pan Tompkins at an earlier stage. In those samples, two filters with a suitable window size are applied in order to eliminate noise. Then the Stationary Wavelet Transform (SWT) based on the quadratic spline wavelet is being applied. Quadratic spline wavelet has been chosen, as it is more successfully applied to ECG signals [6].

After the transformation, zero crossings are detected in the wavelet filter’s high pass coefficients (detail coefficients) at each level in order to detect peaks. A zero crossing in the detail coefficients corresponds to a peak of the signal. So, initially QRS complex is being detected by searching for a pair of local maxima with opposite sign, in the scales of $2^4$ to $2^1$. The Root Mean Square (RMS) is calculated at each scale. The onset and offset of QRS are detected and then we proceed with the detection of P and T waves using a search window as well [7] [8].

2.3. Resilient Back Propagation
In this work we implemented a neural network with resilient back propagation (Rprop) for ECG beat classification. Rprop is an algorithm that resembles quite well with the back propagation algorithm, but is much faster according to the network training. Our system was trained using ECG beats of the MIT/BIH arrhythmia database while the evaluation was done with ECG beats of the QT database. The result of beat evaluation reached 94% by processing all the beats from the latter database. Further evaluation can be done by separating the beats into categories based on the annotations, since a vast amount of beats in these databases are annotated as normal.

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**Figure 2: IHeart flow diagram**
3. Dataset and TCP Transmission
ECG beats of the MIT/BIH arrhythmia database where collected and saved in the Android assets folder in csv format. Three basic threads are being used in order to send the data (csv file) as TCP packets via the network, to receive them and store them in a lock-free queue (ring buffer) and at last to execute the algorithm for QRS detection and visualization of temporal features. This procedure converts the mobile device into an external source that provides the data to the user.

Our application was tested on two different mobile devices namely the Lenovo K50a40 with Android version 5.0 (Lollipop) and the Samsung ACE with Android version 4.0.4.

4. Results
In Figure 2 the flow diagram of our application is being depicted. As we can see the user enters the application and has three options. The first option called “SOS -ALERT CONTACT” navigates the user to the following:

![Figure 3: Welcome Activity](image1)

![Figure 4: Alert Contact via phone call or sms](image2)

The option called “MY RECORDS” leads the user to the following:

![Figure 5: Checking saved records](image3)

The option called “VIEW ECG” leads the user to the main options from where he selects an algorithm and the type of connection he prefers. The data to be analyzed are stored in the assets folder of android as a set of csv files received from the MIT Database and they are obtained in the form of TCP packets over the network. The result of the Pan Tompkins algorithm is visualized with red colored dots, marking the localized QRS complexes of the signal. The results of the wavelets are obtained in the application via a table where QRS, PR, QT, P and T attributes are recorded. Finally, the heart rate is calculated as well.
The attributes mentioned above are calculated for each detected beat. Furthermore, the neural network which was imported into the application, tries to classify each beat given this set of attributes.

Figure 6: Choosing algorithm, csv file and connection
Figure 7: Pan Tompkins and Wavelets

5. Conclusion
The main goal of our work was to design and implement an ECG analysis system. In the future, the above work could be extended by replacing the external source with a real patient and by using sensors, so that a real-time ECG could be obtained.

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