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ECG Analysis Using Wavelet Transform

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***Abstract*— Heart diseases, which are one of the death reasons, are among the several serious problems in this century and as per the latest survey, 60% of the patients die due to Heart diseases. These diseases can be diagnosed by ECG signals. Different artifacts may present in the ECG signals which can thus cause problems for the Specialist to diagnose the diseases. The objective of this paper was to develop a method, based on wavelet decomposition, which would be able to detect and remove artifacts in order to increase the reliability of QRS detection. The work has been done in MATLAB environment.**

***Keywords*— Electrocardiogram, artifact detection, heart analysis, QRS detection, and Matlab.**

I. INTRODUCTION

Electrocardiography (ECG) is one of the most widely used vital sign in clinical monitoring and diagnosis of the health conditions of human heart. Electrocardiography is considered to be one of the most powerful diagnostic tools in medicine. The electrocardiogram signal represents the recording of the electrical potential of the heart. Physicians record ECG signal easily by attaching small electrodes to the human body. Different waves reflect the activity of different areas of the heart. A normal electrocardiogram consists of a P wave, a QRS complex, and a T wave. The P wave is caused by electric currents produced by the depolarization of the atria, while the QRS complex is caused by electric currents produced by the depolarization of the ventricles. The correct identification of the QRS complex is the crucial first step in every ECG analysis. A major problem that is often encountered in QRS detection is the presence of artifacts in the ECG signal like Electrode contact noise, Motion artifacts, Muscle contraction, Baseline drift, Instrumentation noise, and Power line interference.

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The most significant artifact that corrupts ECG signal is Baseline drift [3]. Baseline drift is a noise of low frequency caused by loose connection of electrodes and skin. For correct extraction of the features of the ECG signal, these significant artifacts that corrupt ECG signal have to be cancelled. Different types of digital filters can be used to achieve this cancellation of noises in ECG.

N. Neophytou, A. Kyriakides, C. Pitris develop a method, based on Time-Frequency Analysis (TFA), which would detect and remove artifacts in order to increase the reliability of QRS complex [1]. Marko Velic, Ivan Padavic, Sinisa Car present current achievements in computer aided ECG analysis and future challenges regarding the ECG signal morphology analysis [2]. Rinky Lakhwani, Shahanaz Ayub, and J.P. Saini design digital filters for removing baseline wandering [3]. Manpreet Kaur, Birmohan Singh, J.S.Ubhi, and Seema Rani used digital filtration techniques for removing baseline drift [4]. F. Chiarugi discusses current approaches to the analysis of digital electrocardiographic data [5]. Different problems in different kind of cells or different parts of heart will have corresponding effects in ECG wave's direction and morphology [6] and this connection will be covered in the following Chapters.

Numerous approaches have been proposed for finding the QRS complexes in as ECG. The work proposed in this paper is removal of low frequency interference first i.e. Baseline drift and secondly ECG analysis and QRS complex detection using wavelet transform. An ECG signal corrupted due to abrupt Baseline Drift is shown in fig. 1 and the normal clinical features of the electrocardiogram, which include wave amplitudes and interwave timings is shown in fig. 2.

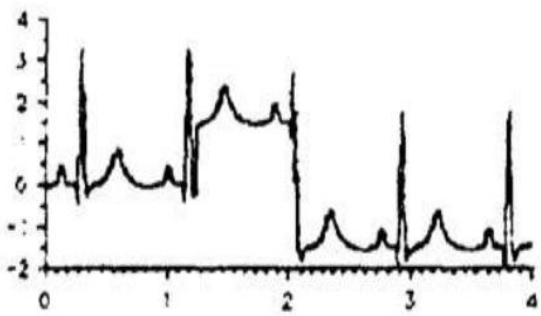

Fig. 1 ECG corrupted due to abrupt Baseline Drift

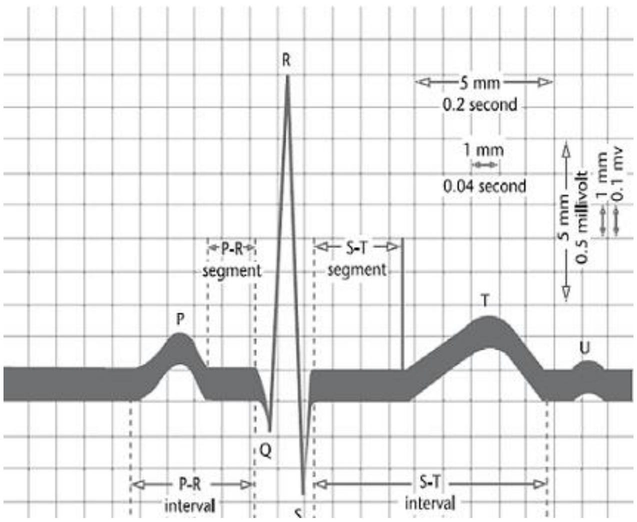

Fig. 2 Normal features of the electrocardiogram

II. ALGORITHM DETAILS

The complete algorithm developed is illustrated as a flow chart in fig. 3. It includes the following steps:

1) Load the ECG signal.
2) Check whether the signal contains artifact or not.
3) If there is no artifact, proceed with QRS detection (step 5). If there is artifact and find it and remove it (step 4).
4) Remove the artifact from the spectrogram.
5) For the artifact-free signal (either directly from step 3 or cleaned from step 4), find the QRS complexes.

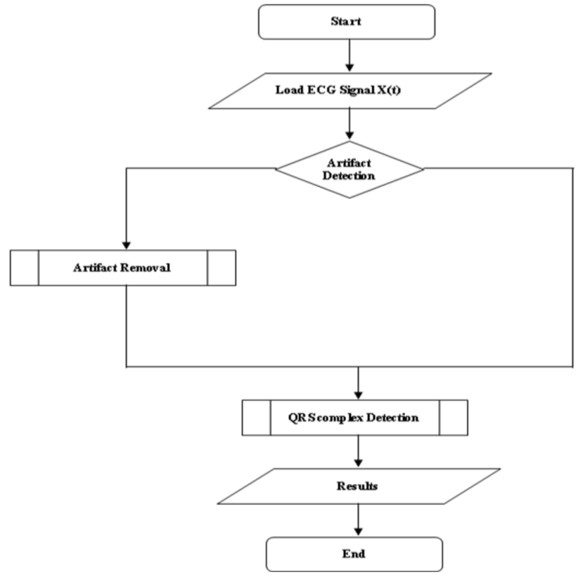

Fig. 3 Flow chart of the proposed algorithm

A. *Artifact Removal*

As is the case with any other signal, filtering of the ECG data is important step in the analysis because of the noise that in the case of ECG recordings can have several causes like interference with other devices and signals, movements under the skin where electrodes are placed. Since the nature of the most of the mentioned noise sources and their features are known. Those features can be used for noise reduction. Ideally, the signal that reach this step do contain artifact, based on the decision of the previous step.

The low pass filtering is used here for smoothing the ECG signal for removal of base line drift from the signal.

B. *QRS Complex Detection*

Biomedical signal processing offers a wide spectrum of solutions and approaches to QRS detection. QRS complex detection is the last step of the proposed algorithm. Artifact-free signals reach this step directly, while artifact-containing signals undergo artifact removal first. Here are the steps for finding the QRS complex are described below.

1) Calculate the coefficients from the ECG signal by applying wavelet transform. The function is expressed as:

   [C, L] = wavedec (X, N, ‘Name’)

   This returns the wavelet decomposition of the signal X at level N, using ‘Name’ wavelet.

2) Calculate the threshold of the signal to separate the peaks that correspond to QRS complexes

from noise. Thresholding is necessary for detecting the QRS complexes.

3) Get their locations of the peaks which are above the threshold from the ECG signal.
4) Find the Q-wave and S-waves by finding the minimum peaks in the range of -10 and +10 samples around each R respectively.

III. RESULTS

The results were obtained using raw ECG data. The graphs for the signal before and after are shown below.

A. Artifact Detection and Removal Result

The "Artifact Detection and Removal" algorithm was applied to signal to decide whether the signal contained artifact or not. Based on this decision, the signal was classified and was further processed accordingly. Hence, this was a very important step for achieving accuracy of QRS detection. Figure shows the result of this algorithm.

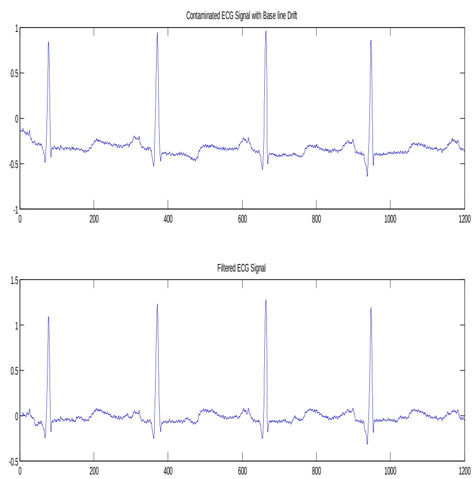

Fig. 4 Result of Artifact Detection and Removal Algorithm

B. QRS Complex Detection Results

QRS complex detection is the last step of the proposed algorithm. The algorithm was applied to all ECG segments which contained both normal and abnormal beats. Ideally, both beats should be recognized as QRS complexes. The correct classification of QRS complexes of artifact free signals is an impressive (all beats correctly identified.) The performance degrades for ECG signals containing either artifacts or abnormal beats.

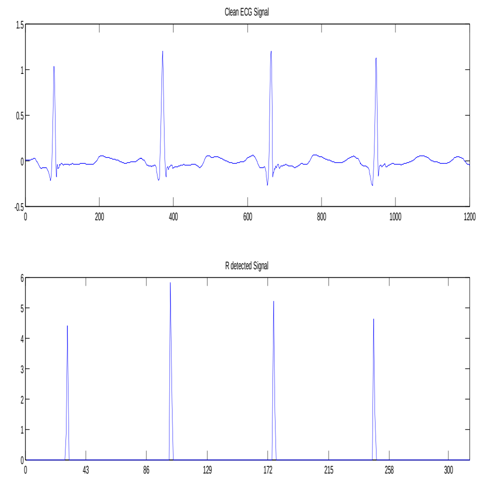

Fig. 5 Result of R Peak Detection

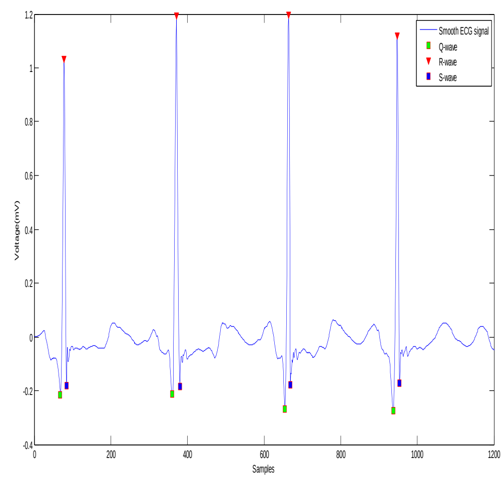

Fig. 6 Result of QRS Complex Detection

IV. CONCLUSION

In conclusion, a method based on Wavelet Transform was developed in order to analyze ECG data. This method gives the best results of detection. This method includes:

a. Determining the presence of artifacts in the signal.
b. Detecting the artifact and removing it.
c. Detecting the QRS complexes.

The proposed method yields 90% correct QRS detection. The improved performance is a result of the detection and removal of ~ 95% of the artifact, when it exists in the signal.

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