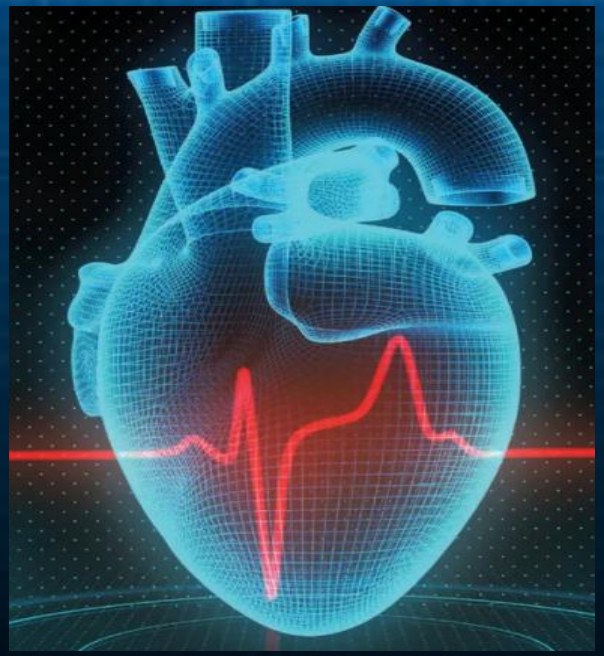
ECG Signal Processing



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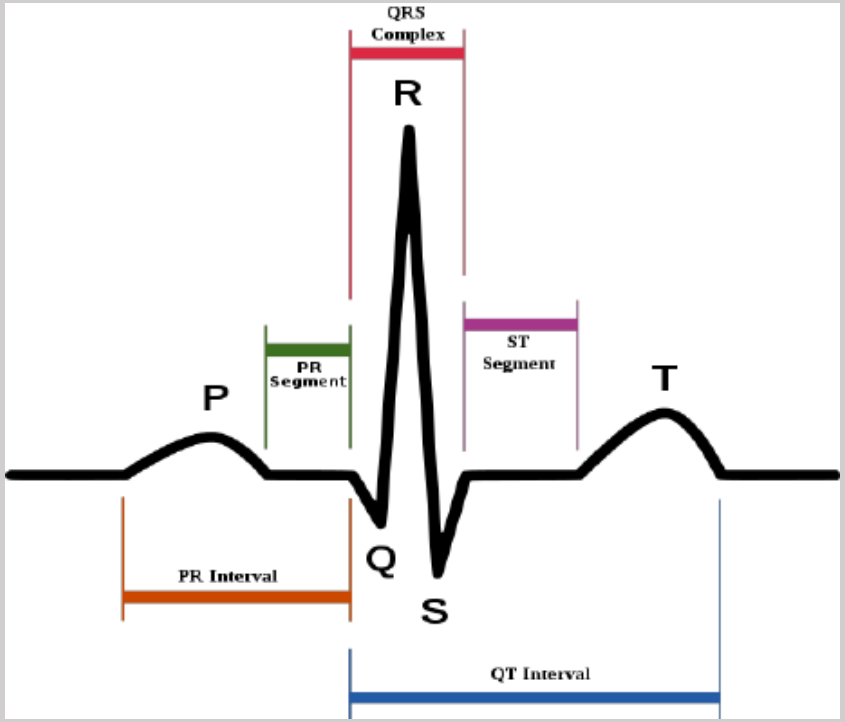
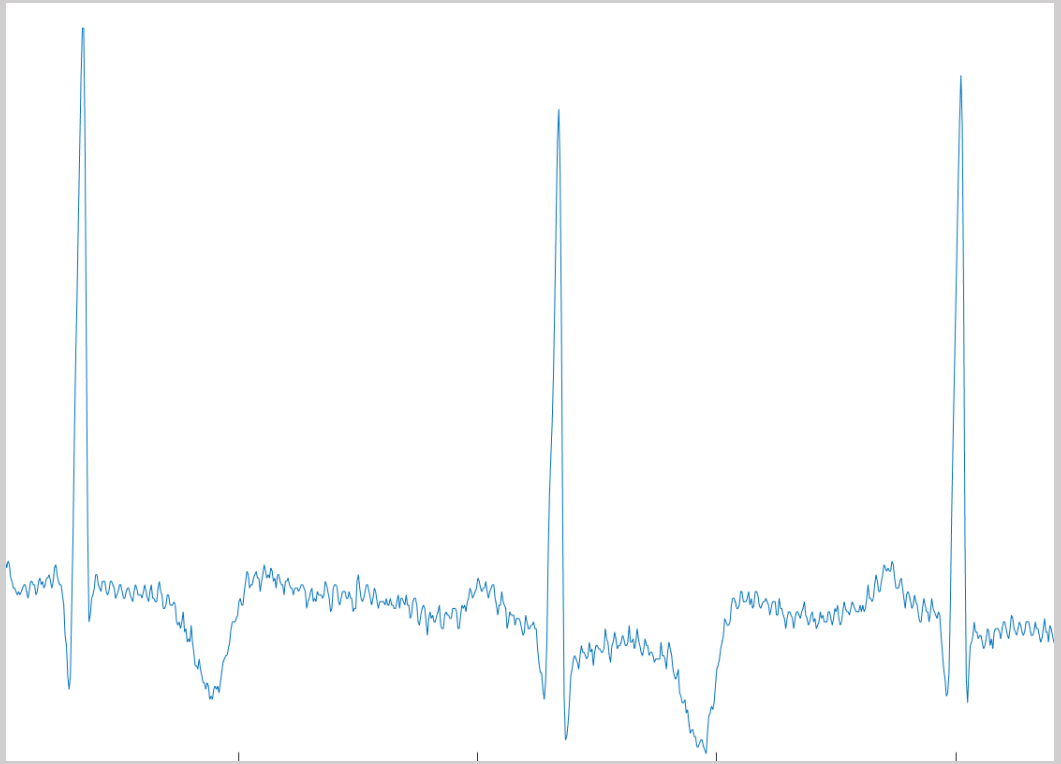
Introduction

Electrocardiogram (ECG) is a signal that describes the electrical activity of the heart. The ECG signal is generated by contraction (depolarization) and relaxation (repolarization) of atrial and ventricular muscles of the heart. The ECG signal contains- a P wave (due to atrial depolarization), a QRS complex (due to atrial repolarization and ventricular depolarization) and a T wave (due to ventricular repolarization).



Artifacts in ECG Signals

Artifacts (noise) are the unwanted signals that are merged with ECG signal. It is necessary to remove them from ECG signals using proper signal processing methods. There are mainly four types of artifacts encountered in ECG signals: baseline wander, powerline interference, EMG noise and electrode motion artifacts.



Objectives

- To observe the ECG signals taken from the database of a MIT-BIH Arrhythmia patients.
- To perform the pre-processing required to remove the Artifacts from the ECG signal using filtering method.
- To detect the PQRST waves of ECG signal and determine the heartbeat of a patient.

ECG Signal Database

- Database used in this project is a standard data taken from MIT-BIH Arrythmia Database.
- Database is observed using two-channel ambulatory ECG recordings and it is obtained from 47 subjects studied by the BIH Arrhythmia Laboratory between 1975 and 1979.
- ECG signal is recorded for 10 seconds, and sampling frequency used is 360Hz with a voltage gain of 200.

Removal of Artifacts from ECG Signal

- **Removal of Baseline Wander**

It can be removed using Discrete Wavelet Transform (DWT). The frequency content of the baseline wander is in the range of 0.67Hz. It will require nine-level decomposition of original signal using DWT to remove the baseline wander of required frequency.

- **Removal of Powerline Interference**

It can be removed using a notch filter concentrated at 50Hz with a 3-dB bandwidth of 5Hz.

- **Removal of EMG – High Frequency Noise**

It can be removed using Discrete Wavelet Transform (DWT). Most of the information available in the ECG signal lies in the range of 0.5-150 Hz. It will require two-level decomposition of original signal using DWT to remove the high frequency noise.

Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) decomposes a signal into a set of mutually orthogonal wavelet basis functions. Wavelet functions are dilated, translated and scaled versions of a common function ϕ, known as the mother wavelet.

DWT has the ability to perform frequency resolution as well as temporal resolution i.e., it can provide information about the frequency components of the wave and its location.

There are several families of wavelet transforms which are identified by their mother wavelet, most common are Haar, Shannon, Daubechies, Spline, Biorthogonal, Mexican hat, etc.

In this project, for the removal of artifacts from the ECG signal, we have used Biorthogonal wavelet transform whereas for the detection PQRST waves in the ECG signal, we have used Daubechies wavelet transform.

Discrete Wavelet Transform (contd.)

To perform the DWT, input signal is given to a low pass filter to obtain the approximate coefficients and simultaneously input signal is also given to a high pass filter to obtain the detailed coefficients.

Detailed coefficients are fixed but approximate coefficients can be modified.

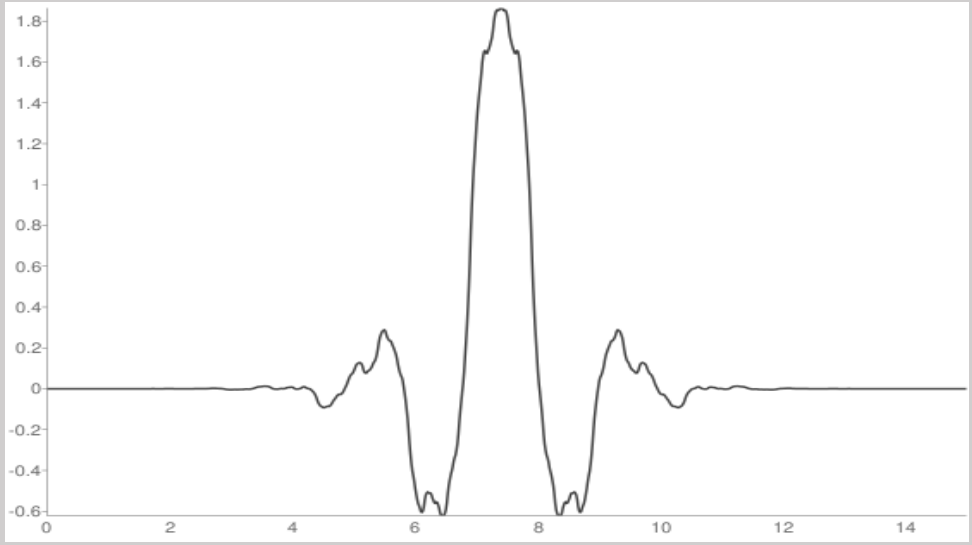
To perform further decomposition of input signal into higher scales, approximate coefficients are down sampled by the factor of 2 and given to another set of high pass and low pass filter to obtain the level 2 approximation and detailed coefficients.

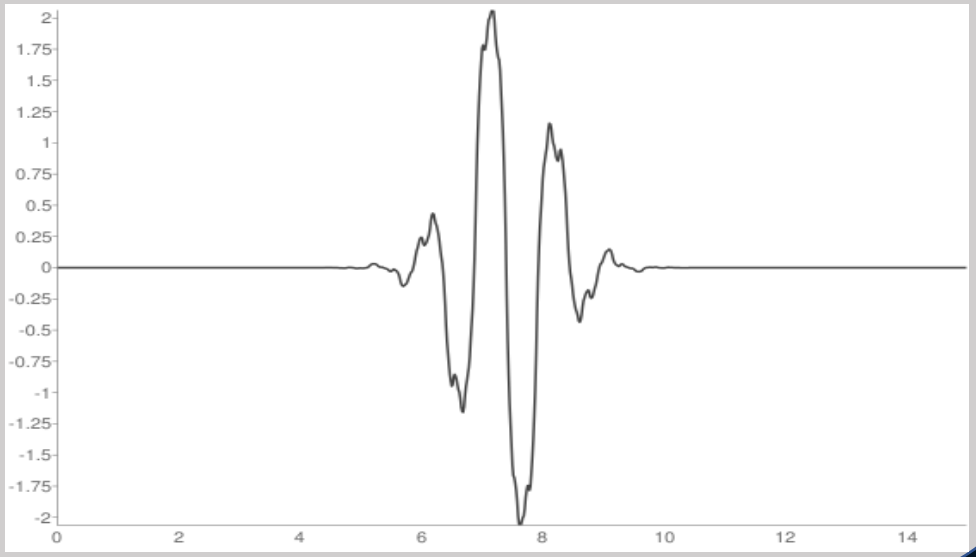
In this project, for the removal of baseline wander noise, we are required to perform nine-level decomposition whereas for the removal of EMG noise, we are required to perform two-level decomposition of the ECG signal.

Biorthogonal Wavelet

Biorthogonal wavelets are families of compactly supported symmetric wavelets. In the biorthogonal case, there are two scaling functions that may generate different multiresolution analysis, and accordingly two different wavelet functions.

Biorthogonal3.7 (bior3.7) is a symmetric biorthogonal wavelet.

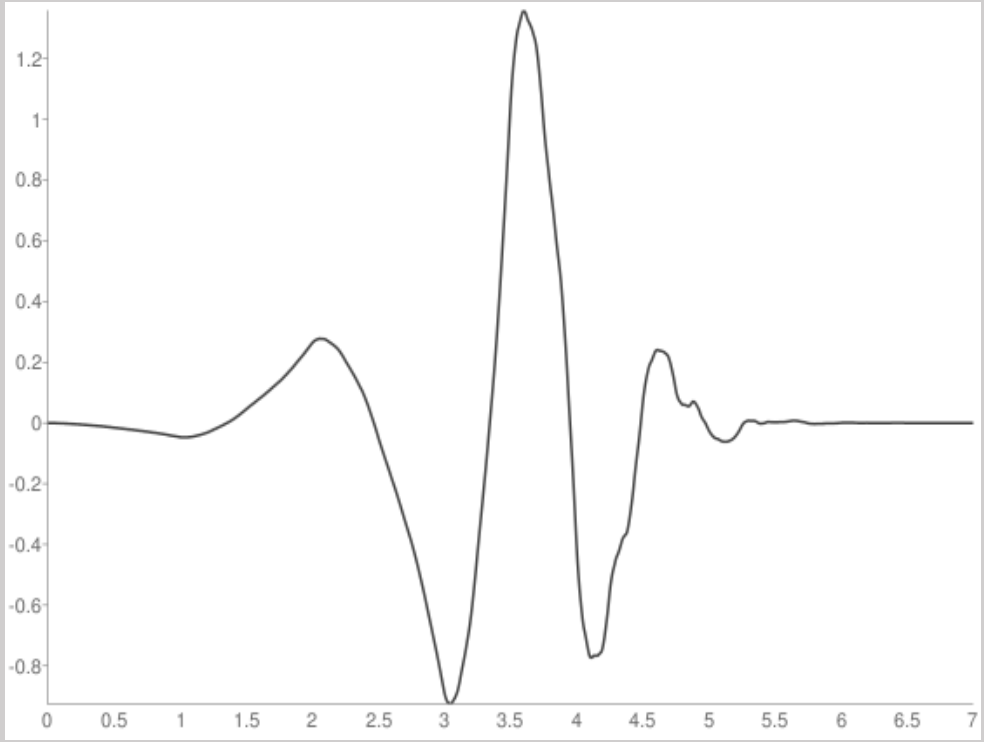




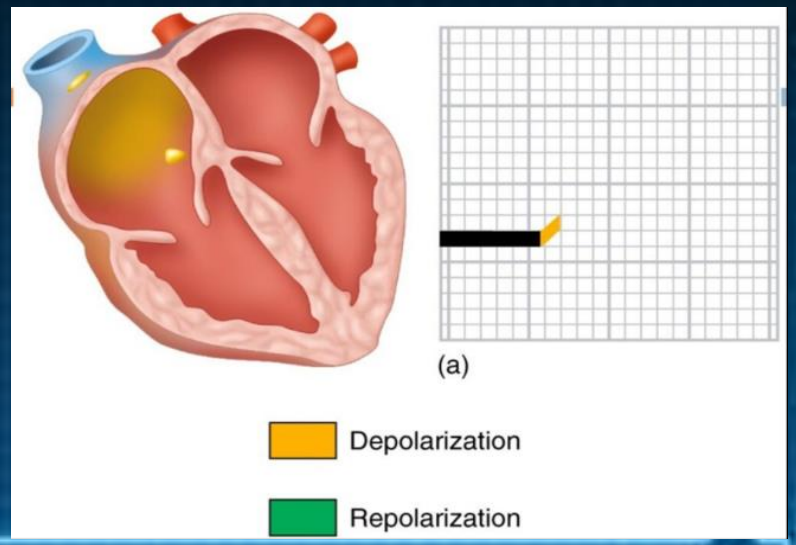
Daubechies Wavelet

Daubechies wavelet was chosen for this project on the basis of the resemblance and similar frequency response characteristics of the DB4 basis function with the ECG waveform.

Daubechies4 (db4) wavelet belongs to asymmetric, orthogonal, biorthogonal and compactly supported families of wavelet.



Generation of PQRST Waves



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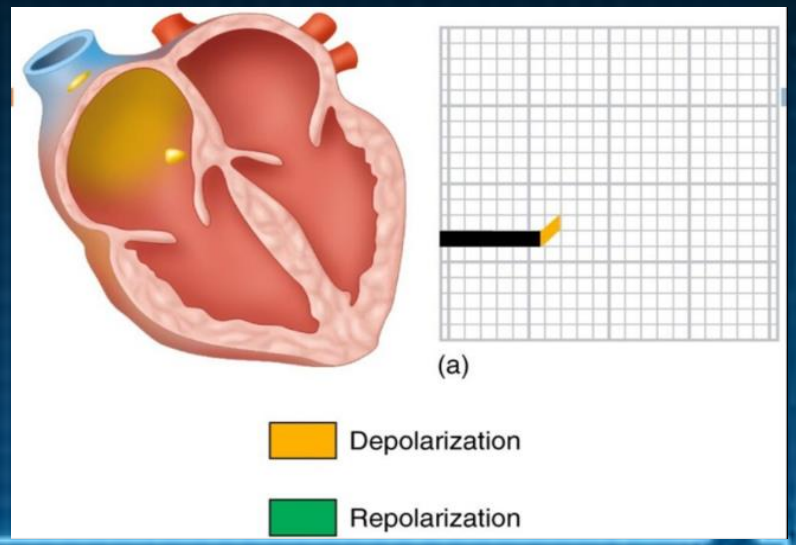

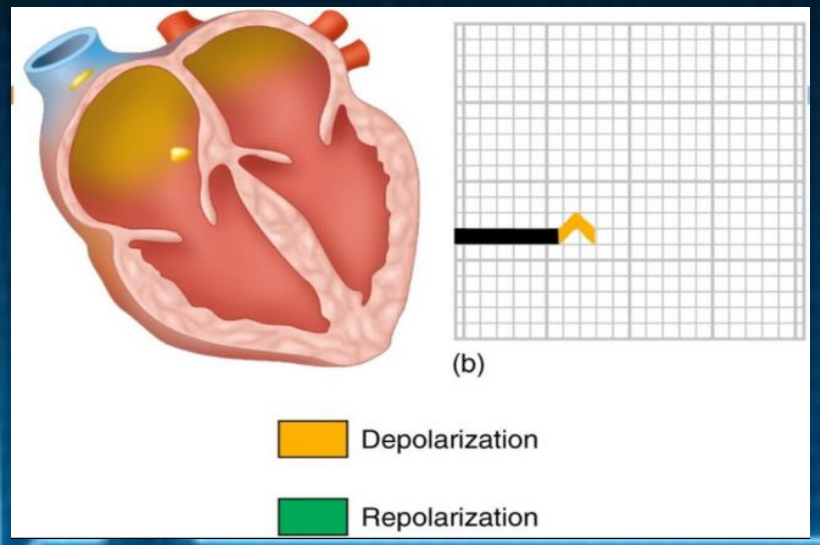

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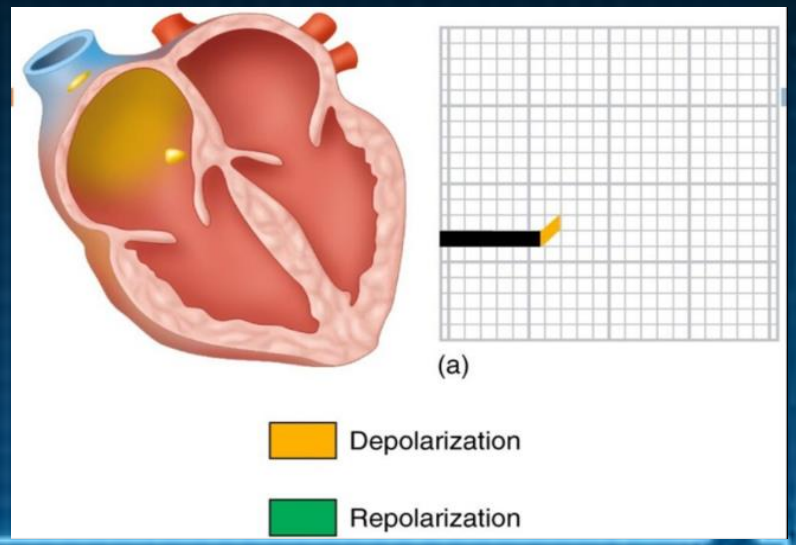

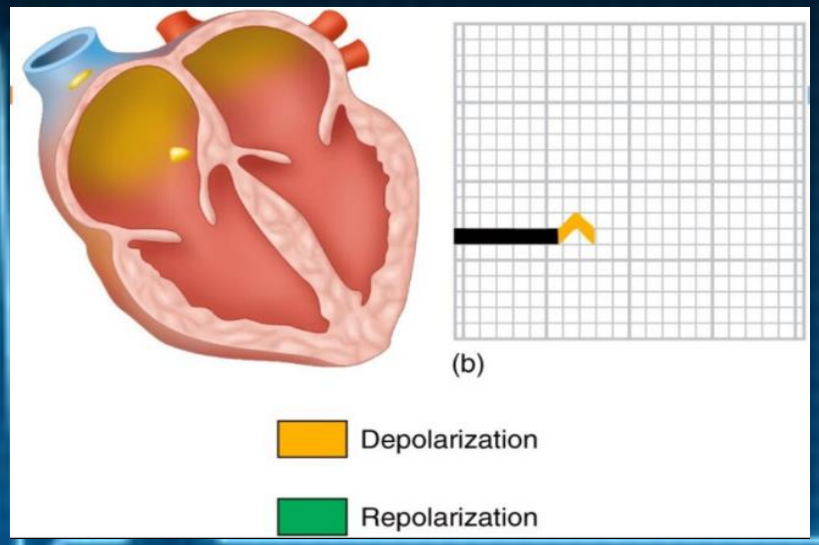

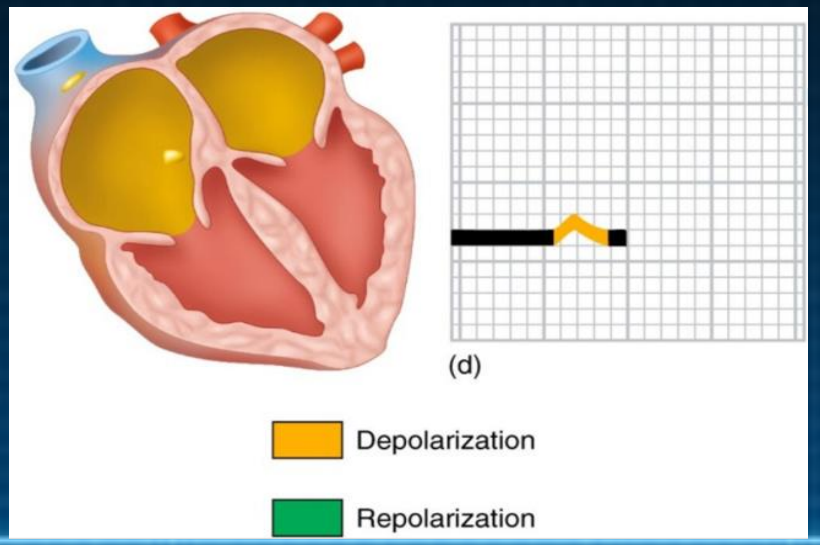

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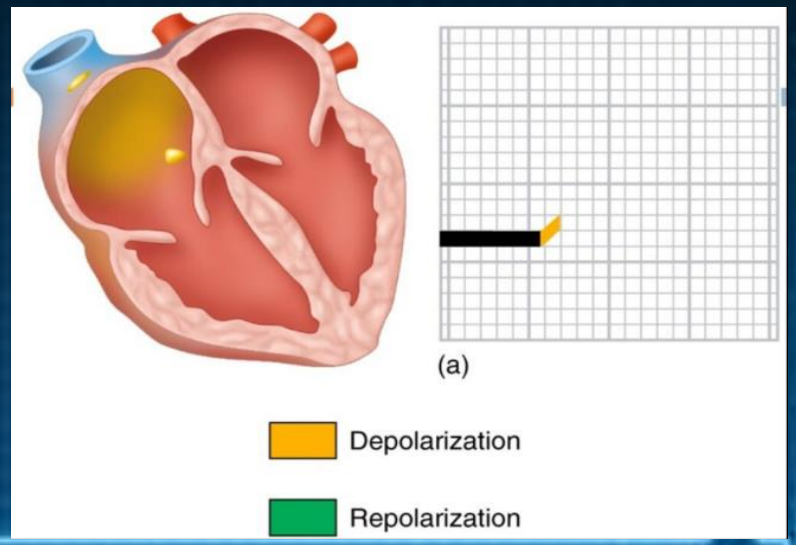

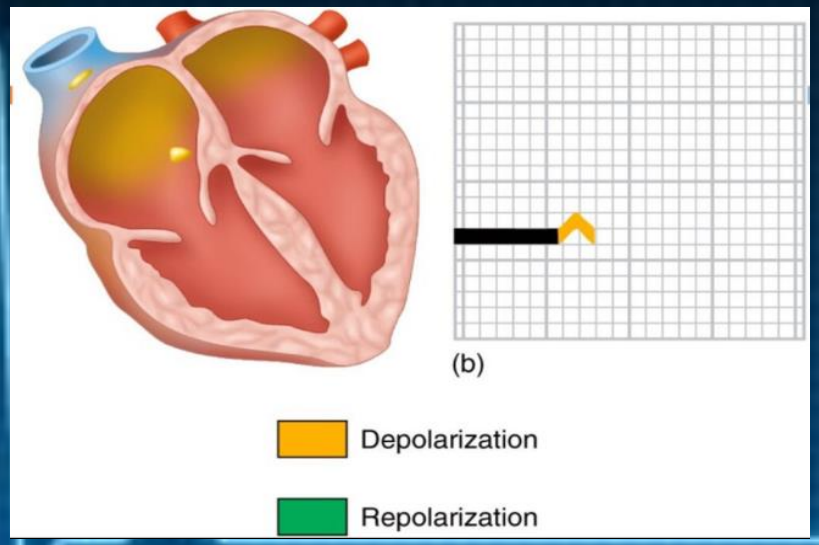

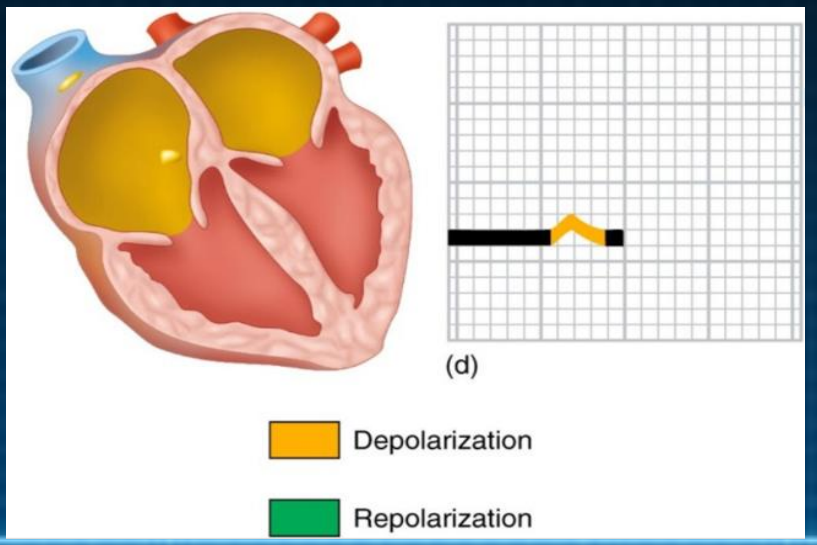

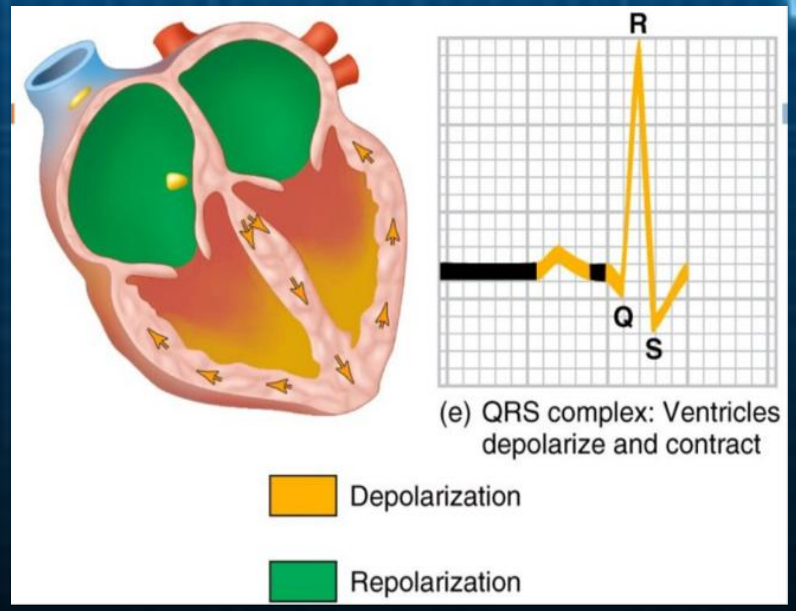

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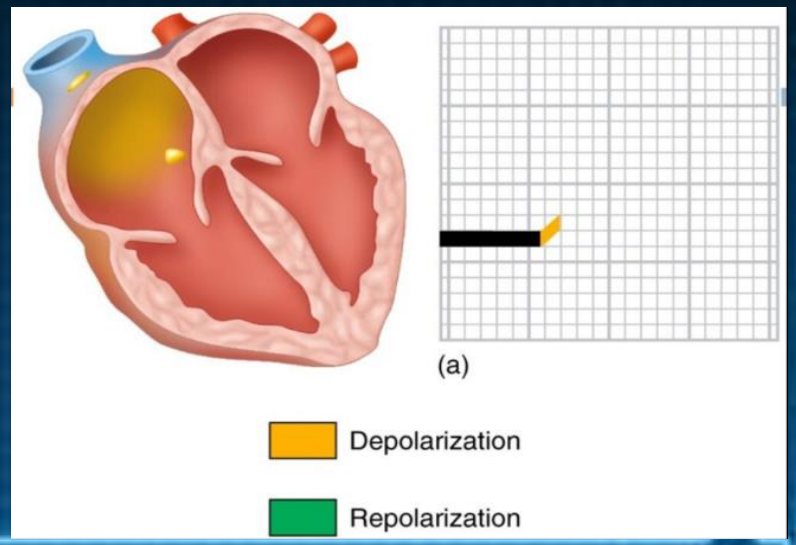

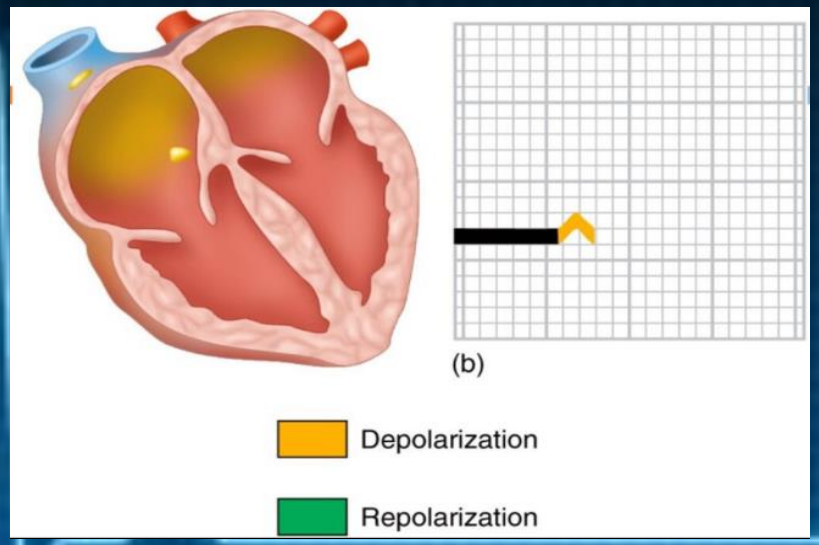

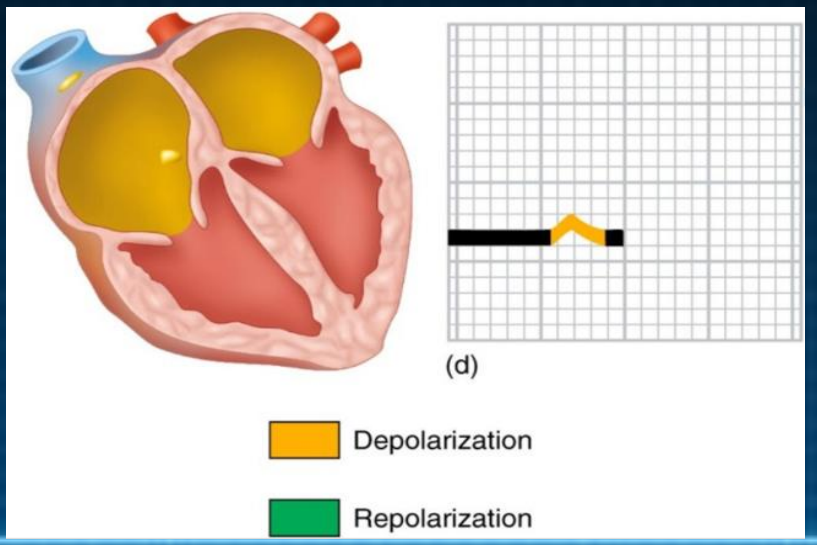

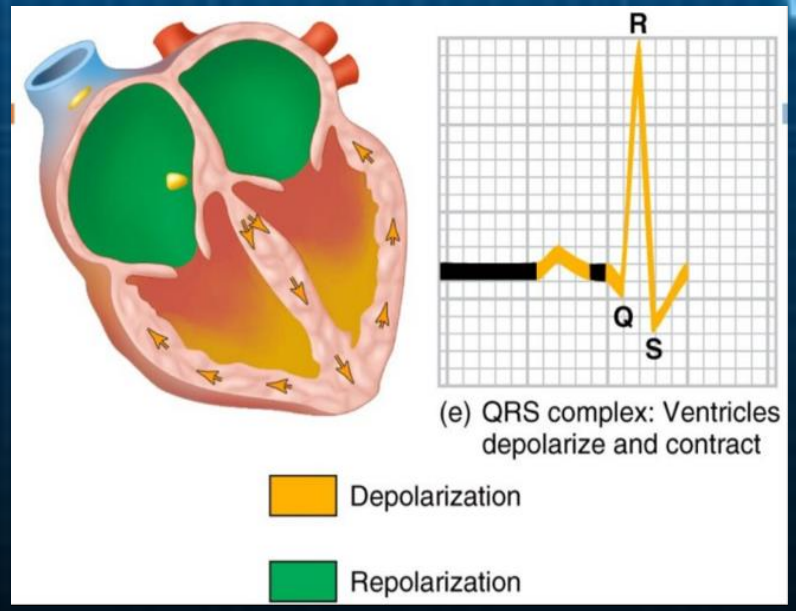

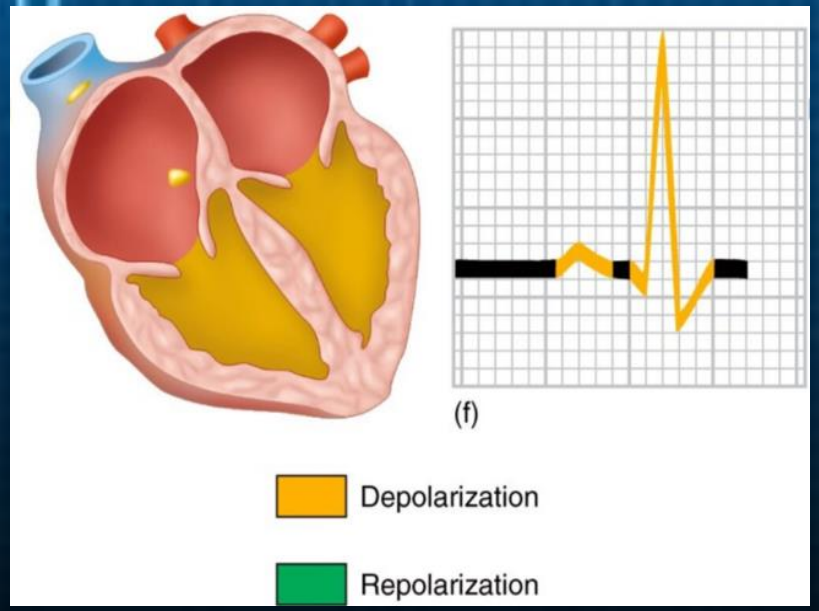

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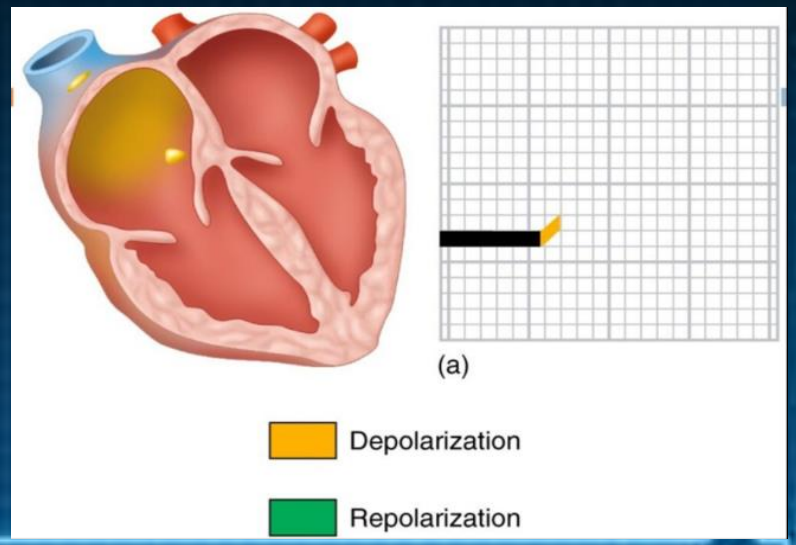

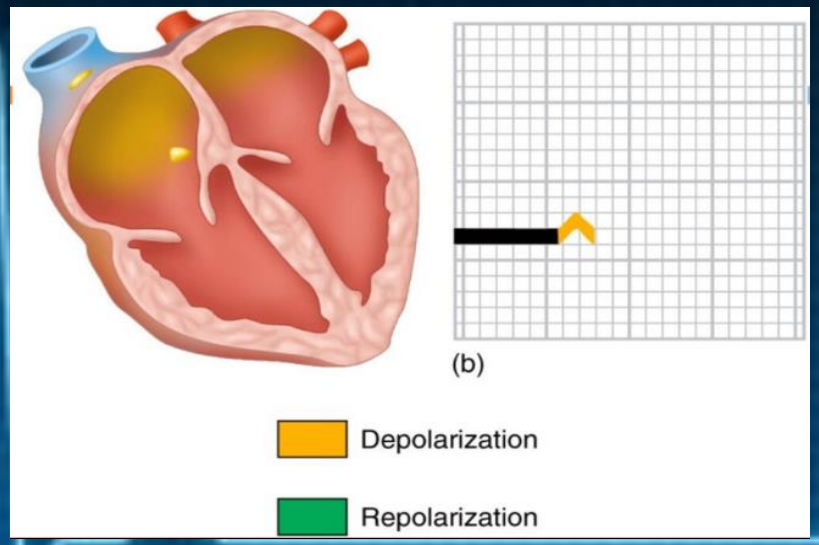

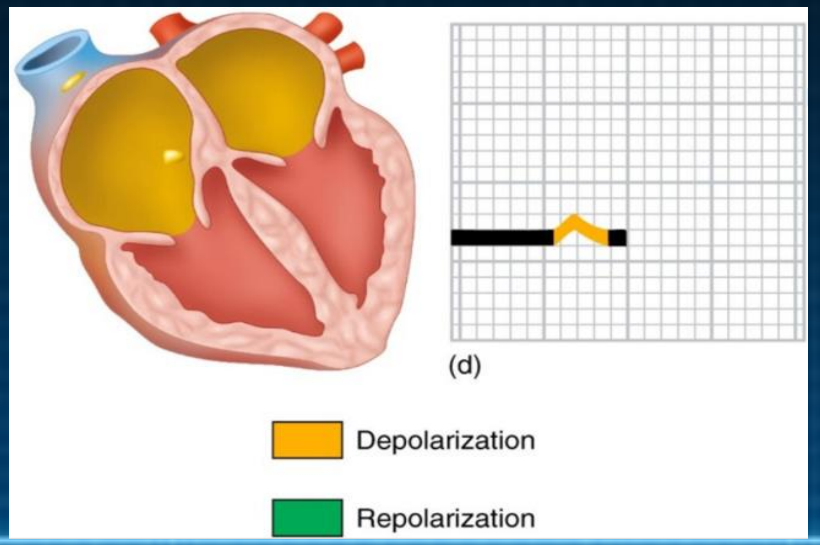

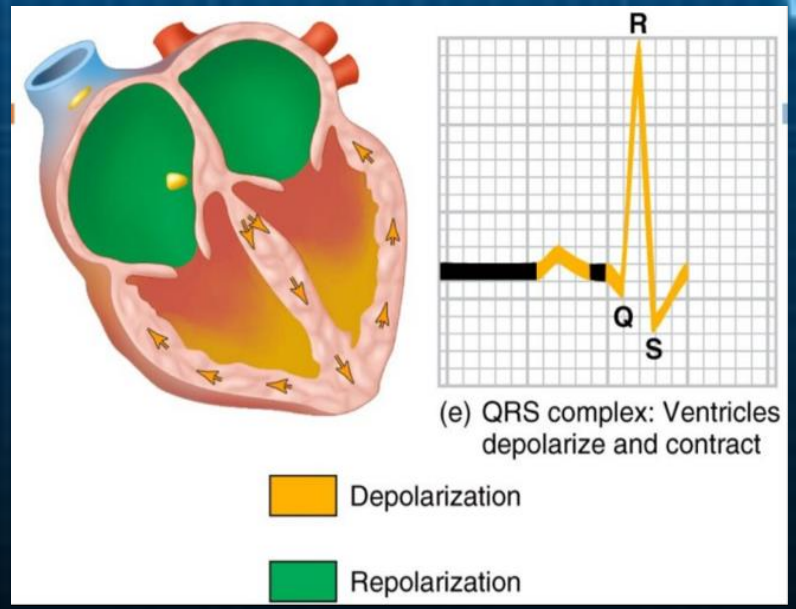

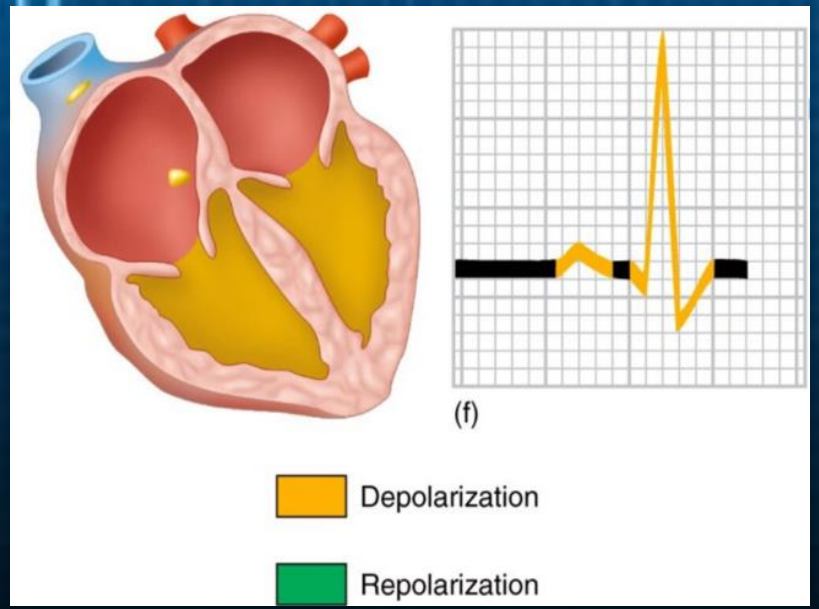

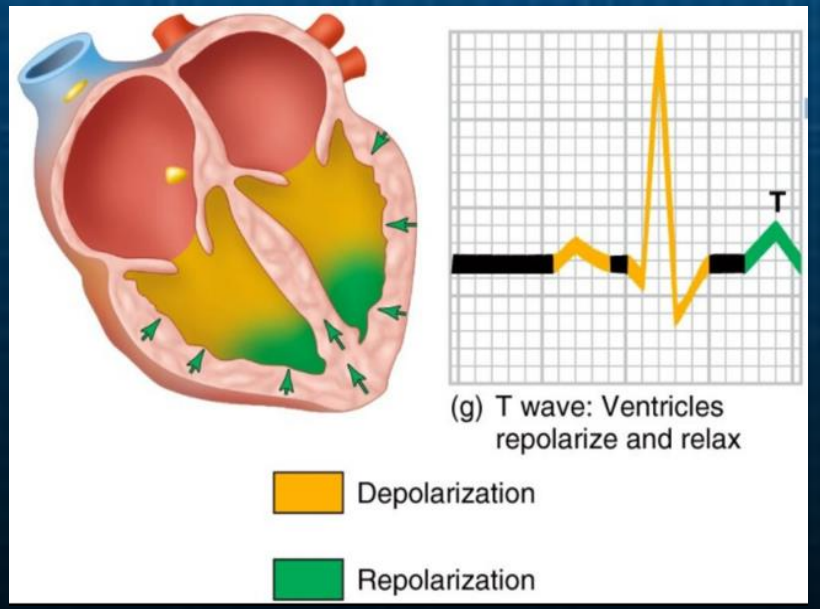

Elements of ECG Signal

- PR Complex: It represents atrial depolarization, and it marks the onset of P wave. Normal duration 0.12-2.0 sec. Prolonged duration of PR complex indicates first degree of heart block.
- QRS Complex: It represents ventricular depolarization. Amplitude of normal QRS complex is 5-30mm high and the duration is 0.06 – 0.12 sec. Its duration and amplitude are useful in diagnosing cardiac arrythmias, myocardial infarction etc.
- QT Complex: It represents ventricular repolarization, and it marks the end of T wave. Normal duration is usually about 0.4 sec.

Scope and Limitation of the study

- In this study, we have used discrete wavelet transform for denoising ECG signals. Discrete Wavelet Transform (DWT) is a transformation that can be used to analyze the temporal and spectral properties of linear and non-stationary signals like audio but almost all real signals are non-linear.
- Therefore, denoising of ECG signals can be done using Empirical Mode Decomposition (EMD) technique.
- Another limitation is the use of notch filter for the removal of powerline interference. So, one can use discrete wavelet transform based on component retrieval technique.