# ECG Signal Analysis

## Group 7

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## Introduction

As part of this group project, we performed a detailed analysis on the ECG signals. To begin with the analysis, we first went through the procedure of how the ECG signal is originally acquired from a person. Following the acquisition part, we understood how information is stored in the ECG signal. As the signal acquisition and understanding the information storage in the signal is done, we move on to calculation of the vital signs from ECG, these include heart rate and breath rate.

## Goals

From the provided ECG signal we need to calculate

1. Heart Rate of the person
2. Breath Rate of the person

## What is ECG?

An ECG signal can be considered as a graph recorded for potential differences created across the body by pumping of the blood from the heart i.e. heartbeat. Generally, these potential differences are created by the electronic impulse traveling from the heart to the whole body, to be specific these impulses are generated by movement of charged ions in the blood that cause polarization and depolarization of the cells.

## How is it acquired?

The potential differences developed on the body are detected by electrodes. We use a specific method called 12 lead or 10 electrode method to obtain the signal. There are numerous other techniques to acquire ECG signals, but this method has been tested out to be most significant. As the name suggests there are 12 leads, this means that there are 12 different graphical angles being produced, but just by the use of 10 electrodes itself. These 12 leads consist of two different sets of leads, chest leads and limb leads.

Of these 10 electrodes, each one of them is placed at the right forearm or wrist, left forearm or wrist, left lower leg, right lower leg, five different locations on the left rib cage, one spot on the right rib cage. The electrode placed at the right lower leg is considered as ground or reference.

## How is it read ?

The 12-lead ECG displays, as the name implies, 12 leads which are derived by means of 10 electrodes. Three of these leads are easy to understand, since they are simply the result of comparing electrical potentials recorded by two electrodes; one electrode is exploring, while the other is a reference electrode. In the remaining 9 leads the exploring electrode is still just one electrode but the reference is obtained by combining two or three electrodes. At any given instant during the cardiac cycle all ECG leads analyze the same electrical events but from different angles which gives us the magnitude and direction of it.

## How is it stored ?

In the heart the conduction begins in the sinoatrial node (SA Node) which is located in the right atrium of the heart. From this the conduction goes to the Atrial-Ventricular node(AV node) . This is located between the right atrium and ventricle. From this node the conduction passes to the bundle of His and then gets bifurcated into two parts the right and left bundle of his and finally at the apex of the heart the conduction is passed into the Purkinje fibers .Here conduction is basically due to the polarization and depolarization of ions.

The information of the above conduction activity is displayed in the form of an electrical signal called ECGsignal.

The ECG signal consists of 3 parts

- P wave - This part of ECG arises due to atrial depolarization
- QRS complex - This part of ECG arises due to ventricular depolarization. In this part the atrial repolarization also takes place. As the ventricular depolarization is a stronger contraction, the atrial repolarization is generally masked off.
- T wave - This part of ECG arises due to the ventricular repolarization

### Why 12 lead?

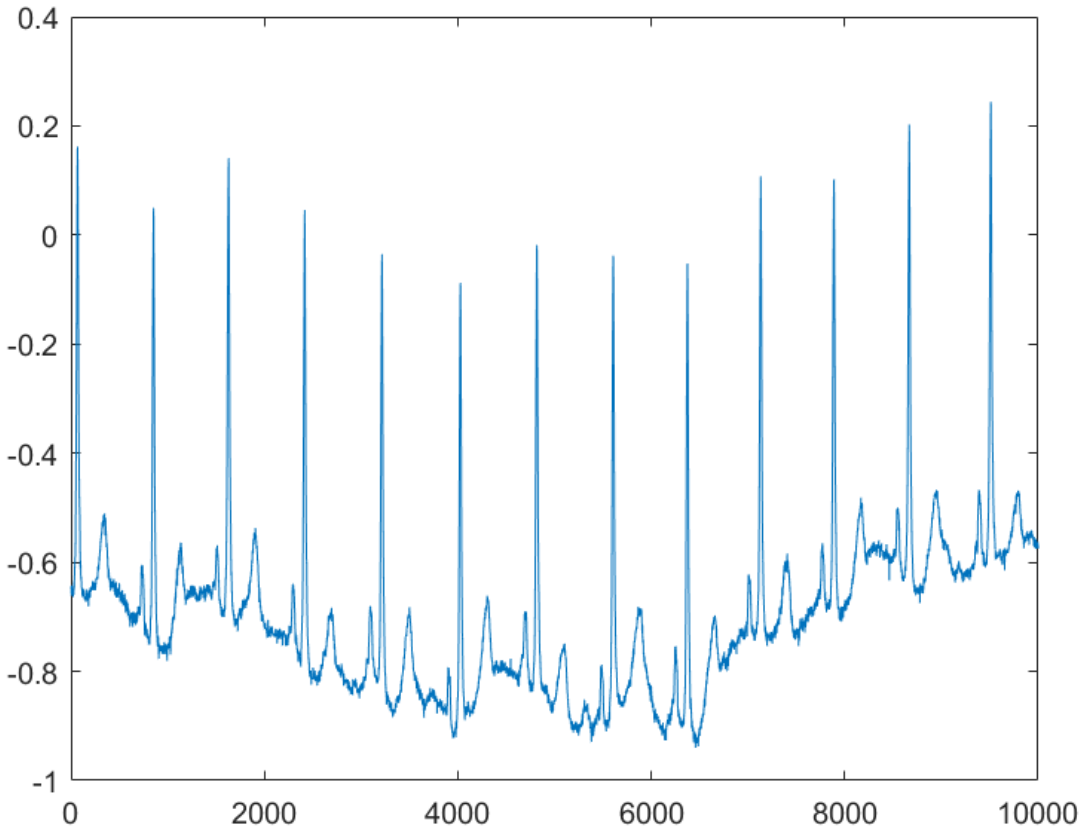
With the increase in the number of leads used to acquire ECG signals, we get to know more about the disorders of the person's heart. With the decrease of the number of leads there is an increase in the accuracy of electrical activity. So, to maintain balance among both, we use 12 leads, which is the best case to provide both.

## Heart Rate

Frequency at which the heart beats is known as heart rate. Normally, for a healthy human heart rate ranges from 60 to 100 beats per minute.

From the given ECG signal, there are many ways to obtain the heart rate of the person. The technique we used to find out heart rate is clearly described below.

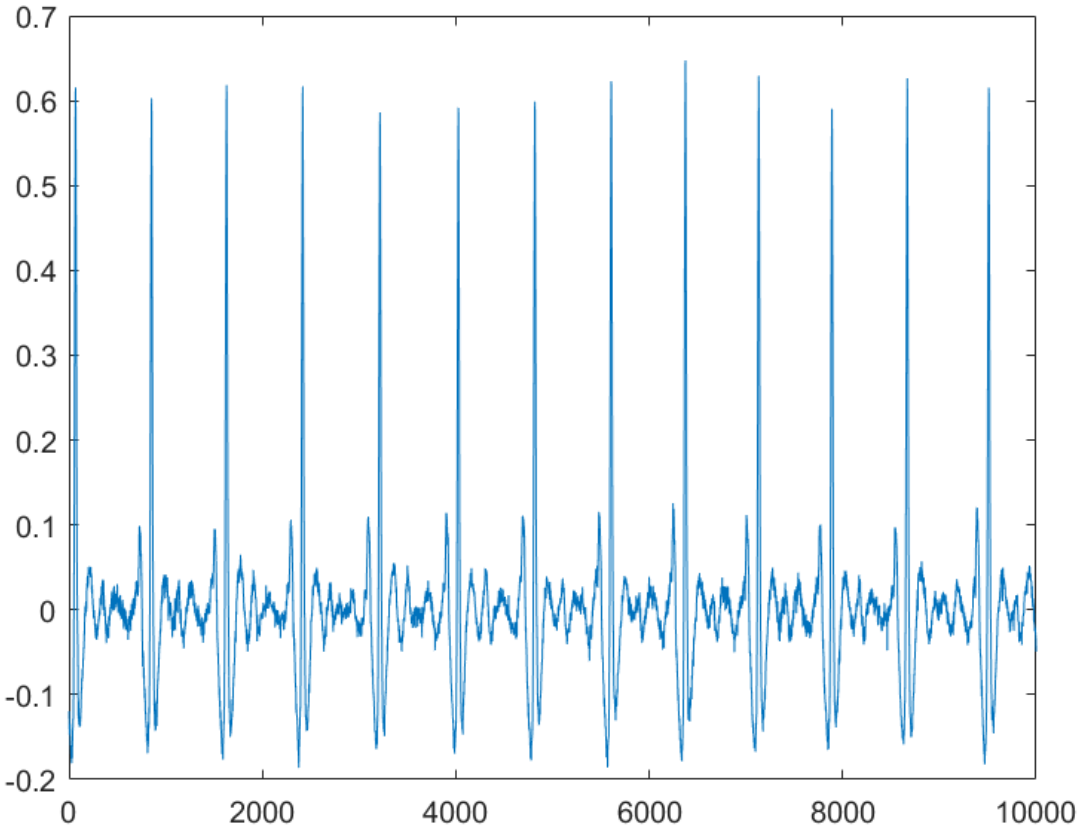
- Firstly, from the data set that we took, we plotted the ECG plot for the first ten seconds. Original ECG signal for the first ten seconds is depicted below.




In the above graph, Y-axis represents the potential in volts and X-axis represents time in milliseconds.

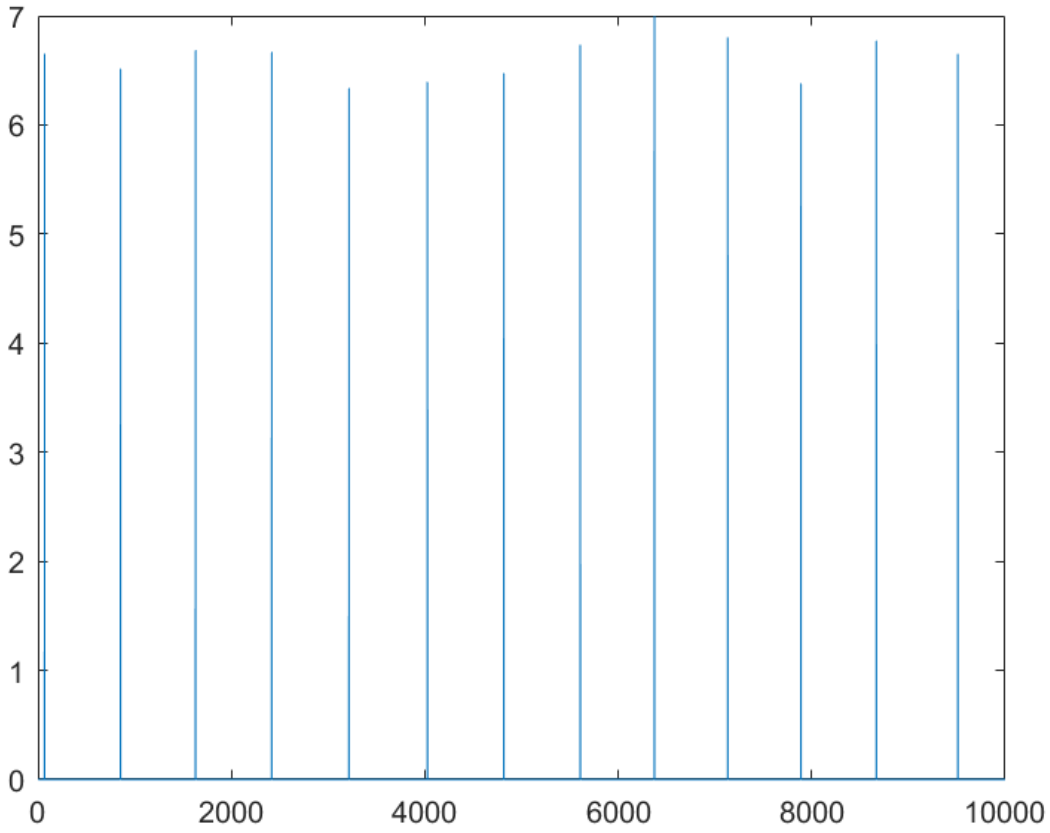
- Now from the ECG signal plotted it is clearly evident that graph structure is not aligned properly to maintain a threshold to determine R-peaks. This non alignment of PQRS complexes is due to the low frequencies that are caused by other minor

activities in the human body. So, now we try to remove these low frequency components. This is done by finding the FFT of the signal and making low frequency value's magnitude 0 and then performing inverse FFT of the signal. The resultant signal is depicted below.




In the above graph, Y-axis represents the potential in volts and X-axis represents time in milliseconds.

- As the alignment is dealt properly, we now need to find the R-peaks of the signal. R-peaks indicates the pumping of the blood by the heart. So, every R-peak in an ECG signal indicates an individual heartbeat. Now, calculation of the number of R-peaks in particular time is enough to find out the heart beat. In this algorithm, we found out R-peaks by using the windowing method. By considering that human heartbeat can never exceed 200 beats per minute, we took window size as 300 milliseconds. Now, we divide the time of signal into windows of interval 300 milliseconds and make the maximum value in that particular interval as a peak. After finding the peaks, by considering a threshold voltage level, we label peak values above threshold as R-peak values. Now, the calculated R-peaks of the above signal are depicted below.




- Now, as we know the total number of R-peaks in the total time, we can calculate the heart beat rate by using formula

$$Heart\ Rate\ = (Number\ of\ R\ -\ peaks\ in\ time\ interval\ /\ Time\ interval\ in\ seconds)\ *\ 60$$

Final screen shot of computed heart rate is shown below.

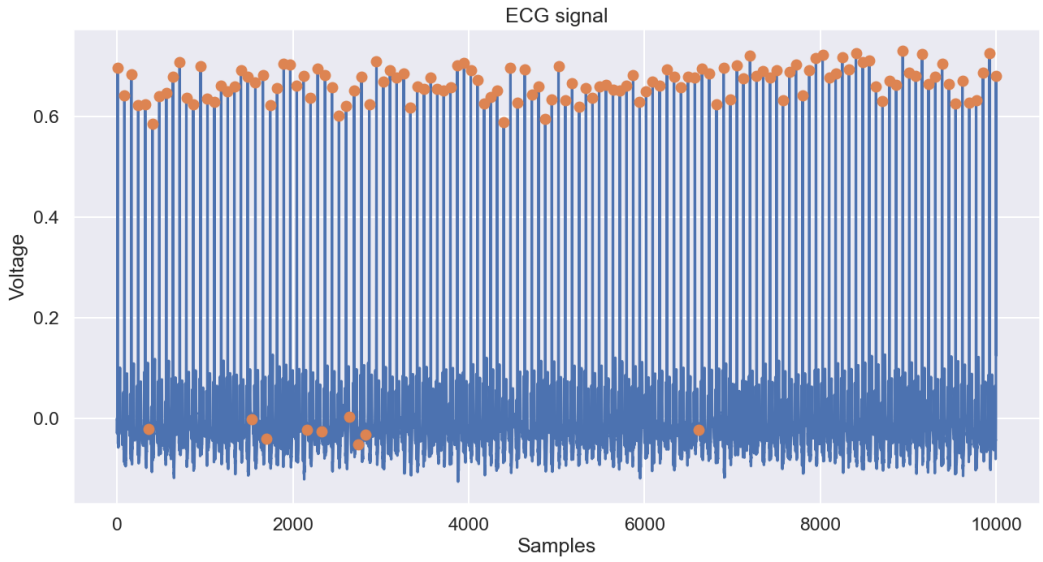
```
>> ecg2
Average Heart Rate =
   76.2550
```

## Breath Rate

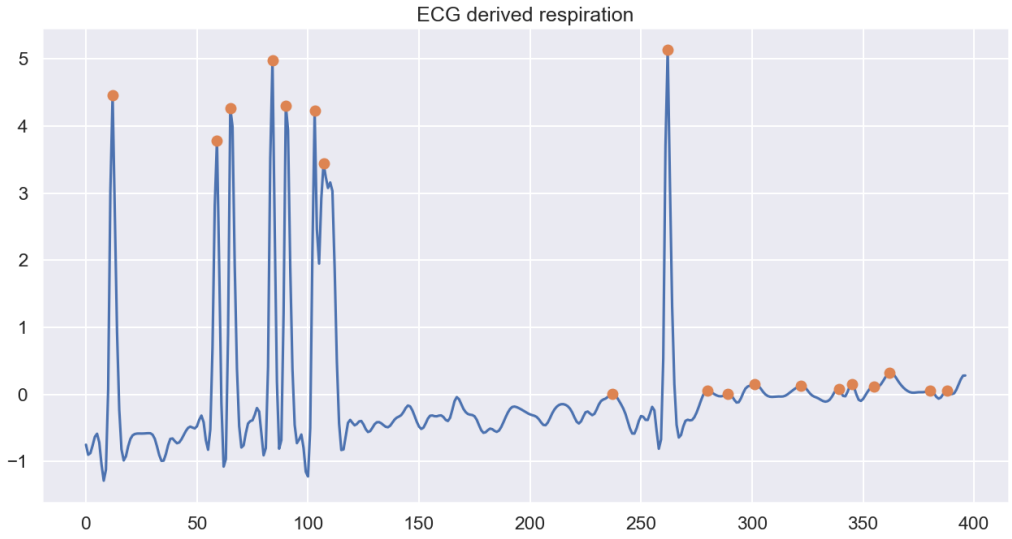
Frequency at which breaths are taken is known as breath rate. Normally, for a healthy human breath rate ranges from 12 to 20 breaths per minute.

The breath rate of a person can be calculated from an ECG signal as well. There are many ways to calculate breath rate, one of the methods that we used is described below.

- Firstly, we load the data set to a local variable by using mat4py package. Now, we resample the acquired data and plot the signal for the required time interval. From the resampled signal we calculate the R-peaks and store their positions.




- Now from the calculated R-peaks, we form a signal and interpolate the signal. We perform upsampling before performing interpolation. Here, interpolation of the R-R interval is done by using a cubic spline. Following the interpolation, we detrend the signal and normalize it.
- Now, we computed a signal known as ECG derived respiratory signal. Now, we find out the mean respiratory rate by using the specified formula.




$$Breath\ Rate\ = (Number\ of\ respiratory\ peaks\ in\ time\ interval\ /\ Time\ interval\ in\ seconds)\ *\ 60$$

Now, the screenshot of the final output results are shown below.

```
rithvik@RITHVIK:~/sp$ python3 tmp.py
Mean respiratory rate: 0.19 Hz
Mean respiratory period: 5.26 seconds
Respiration RMS: 8.78 seconds
Respiration STD: 7.06 seconds
Maximum frequency: 0.16 Hz
rithvik@RITHVIK:~/sp$
```

## Data Set

We considered the data set, which is directly taken from the internet. You can get the data set in the link.

## Future Aspects

- The hardware(the lead system) is further being developed so that the noise at the output can be eliminated .Also the software can be developed such as using the low pass filtering techniques which eliminates the noise.
- We can also develop the hardware further such that a wireless transmission of the ECG can take place. Recently the remote ECG monitoring system has come into use which has the wireless transmission technique .
- This work can be even extended by using cheap hardware so that the people in rural areas also can use this and need not travel too far for a regular checkup
- The ECG signal processing algorithm is limited to the processing of those waves which display the P, Q, R, S, T peaks. Any absence of these peaks cannot be detected. The algorithm is being developed further so that any change in the wave shape can be detected
- We can do further analysis on the ECG signal which can help us to detect more heart related diseases (like hypertension).