Implementation of DSP concepts on ECG signal for removing noise using particular filters and comparative study of DCT and DFT compression of ECG signal

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1 Abstract

The objective of this report is to implement digital signal processing techniques on ECG signal.The ECG signal consists of different peaks and troughs.It is a periodic signal and the period is calculated with the help of RR interval time.The peak detection was done using thresholding technique and the corresponding timestamps were noted and RR interval was stored. The ECG signal recorded is generally distorted by the power line interference and baseline wander interference. The interferences were filtered out by using appropriate filters and the comparison was done using different evaluation metrics.The compression was done on the ECG signal using different transforms and the signal was reconstructed and the comparison was done. The transforms used are Discrete Cosine transform,Discrete Fourier transform and Wavelet transforms.

2 Introduction

ECG signal is a natural signal and hence the interferences that occur on the signal are due to some practical causes.The two main interferences it faces are power line interference and baseline wander noise.Their are various filters to remove the noise and the most effective one can be concluded by using some metrics like mean square error..The DCT and DWT are also applied on ECG signal to get the extent of compression of the signal.

3 Datasets

The Dataset used is a Matlab file that is an ecg signal recorded from a person

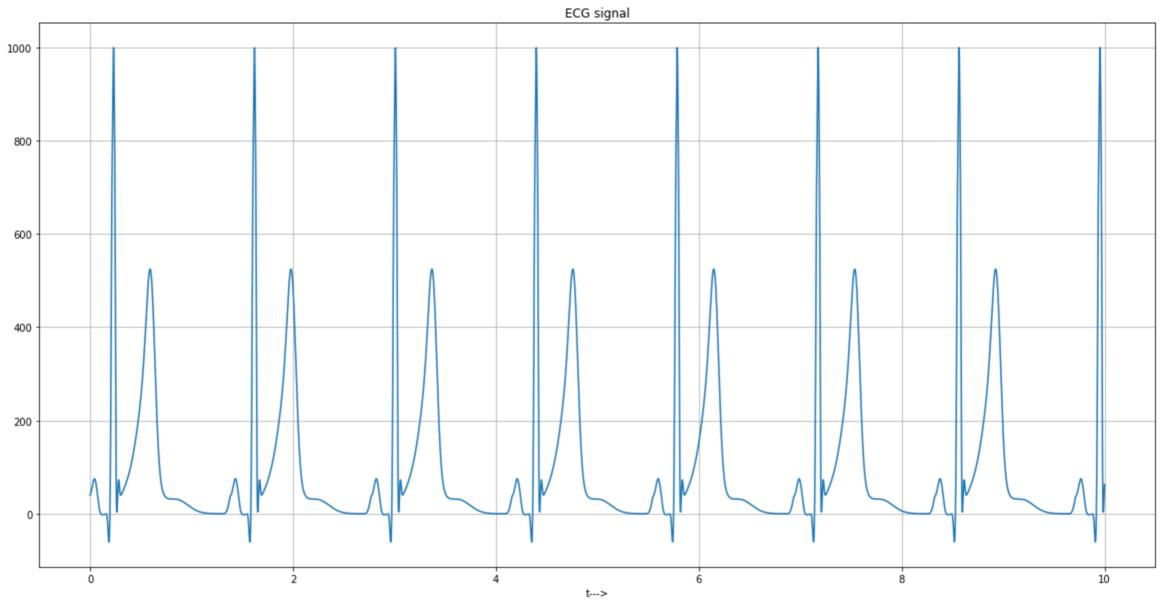


Figure 1: ECG Signal

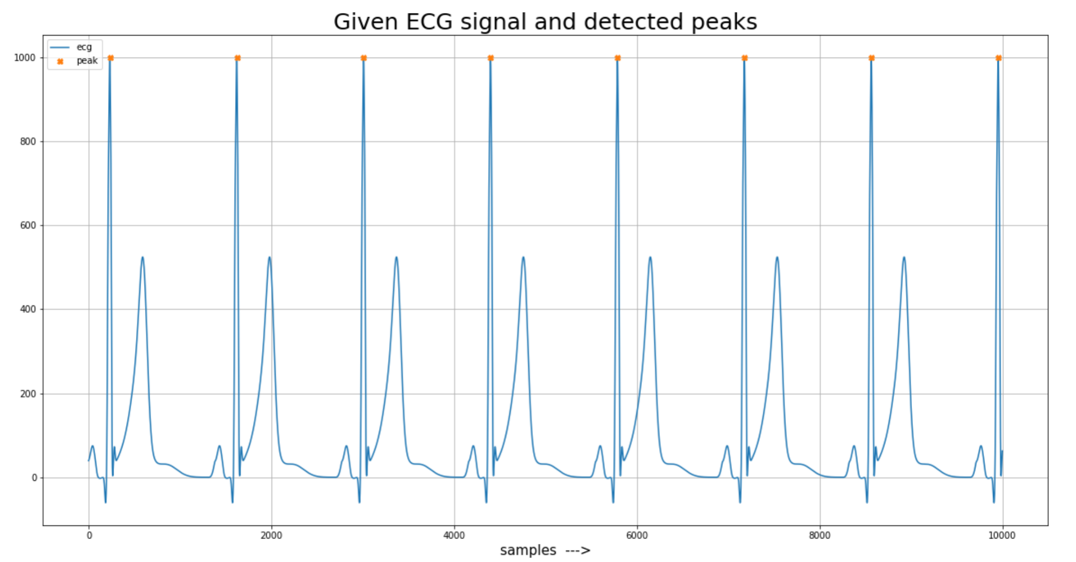
4 Evaluation Metrics

The evaluation metris used is Percentage mean square difference(PRD)

$$PRD = 100 * \sqrt{\frac{\sum_{n=0}^{N-1}(x_{original}[n] - x_{filtered}[n])^2}{\sum_{n=0}^{N-1} x_{original}[n]^2}} \tag{1}$$

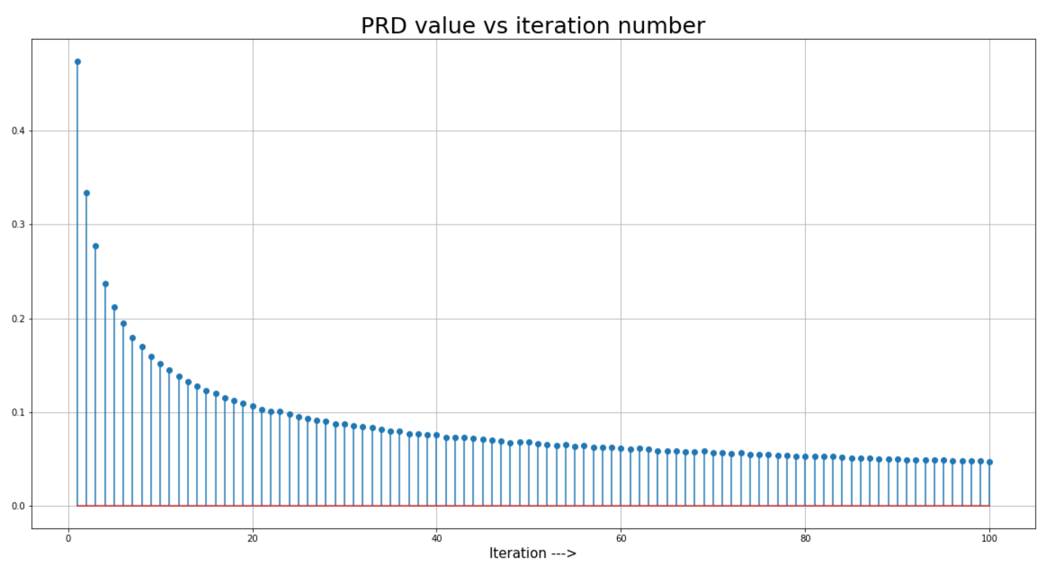
5 Methodology

The peak detection of ECG signal is done using thresholding of the signal.An appropriate threshold is chosen and the and the maximum value above it is taken as the peak value.The peak detection was done using the find peaks function of scipy library.



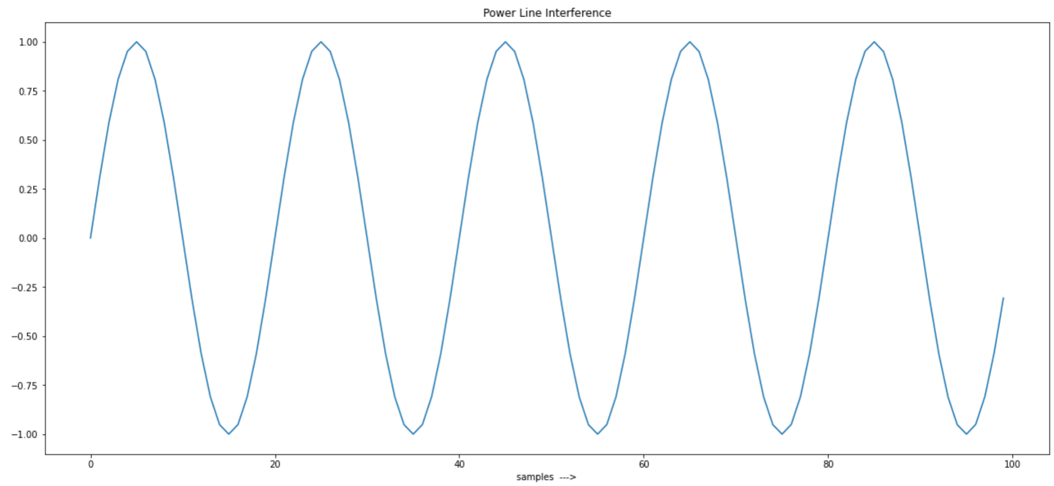
The RR interval of ECG signal was also calculated after taking the difference of the corresponding timestamps of the peaks.The approximate RR interval came out to be around 1.4s.

Synchronous averaging is done on the signal to remove the random noise of the Synchronized or ensemble averaging is possible when: The signal is statistically stationary, (quasi-)periodic, or cyclo-stationary. Multiple realizations or copies of the signal of interest are available.The multiple realizations or ensembles are added and averaged and the noise gets cancelled out.Here Percentage mean square difference is used as a metric to show its decreasing trend as the number of iterations is increased which is shown in the following image.



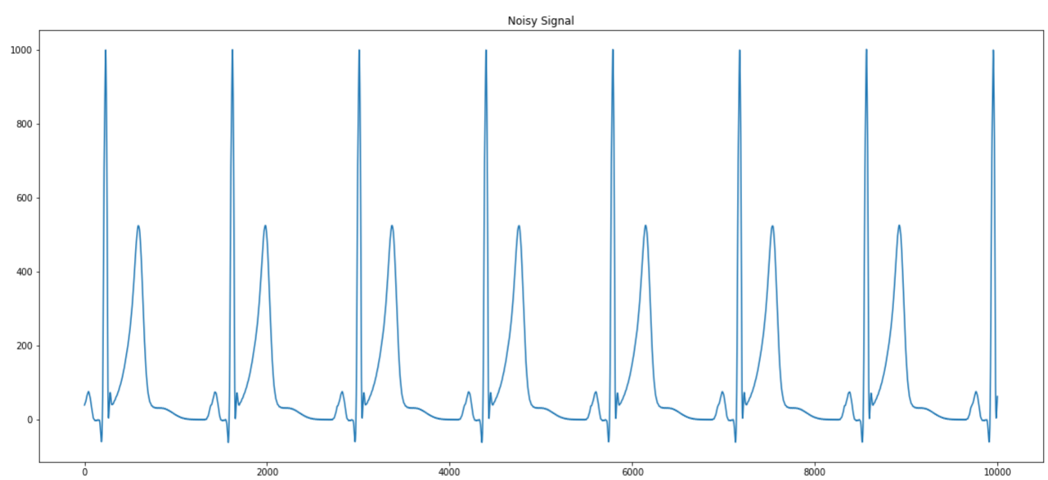
The most commonly encountered periodic artifact in biomedical signals is the power-line interference at 50 Hz or 60 Hz. If the power-line waveform is not a pure sinusoid due to distortions or clipping, harmonics of the fundamental frequency could also appear.

Harmonics will also appear if the interference is a periodic waveform that is not a sinusoid (such as rectangular pulses).

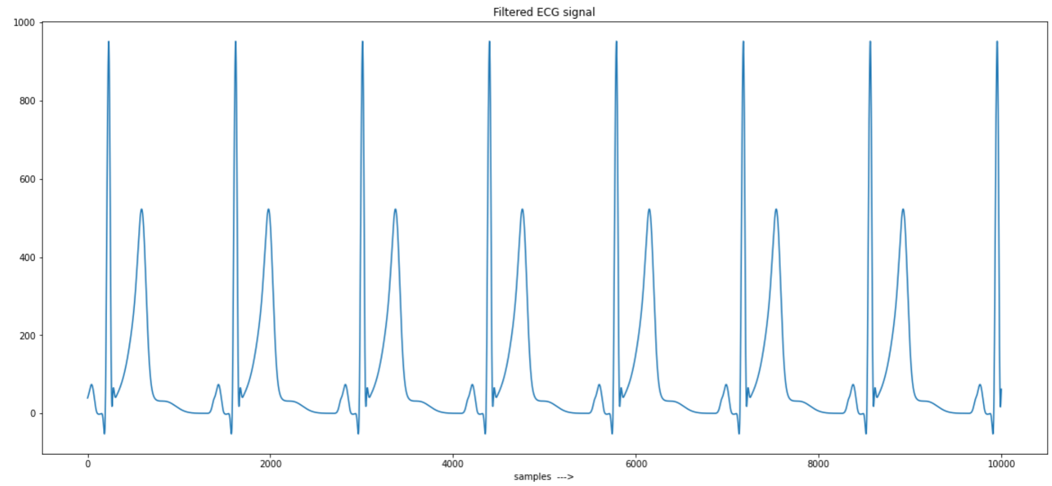


5.1 Poweline Interference

Power-line interference may be difficult to detect visually in signals having non-specific waveforms such as the PCG or EMG; however, the interference is easily visible if present on well-defined signal waveforms such as the ECG or carotid pulse signals. In either case, the power spectrum of the signal should provide a clear indication of the presence of power-line interference as an impulse or spike at 50 Hz or 60 Hz, harmonics, if present, will appear as additional spikes at integral multiples of the fundamental frequency. Here we are not taking the harmonics rather we are only taking a 50Hz sinusoid.



Here,the first filter used is IIR notch filter which removes a particular frequency while the others are not disturbed.It is a frequency domain filter used to remove a particular frequency.



The second filter used here is the mean median filter.It is a time-domain filter for which we calculate mean and median of a particular window and then form the signal from the mean and median data of the window and then adding them after multiplyng them with alpha and 1-alpha respectively.

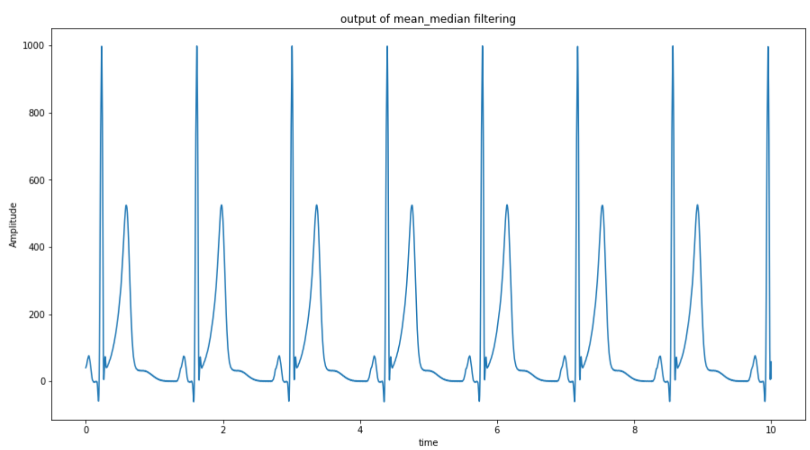


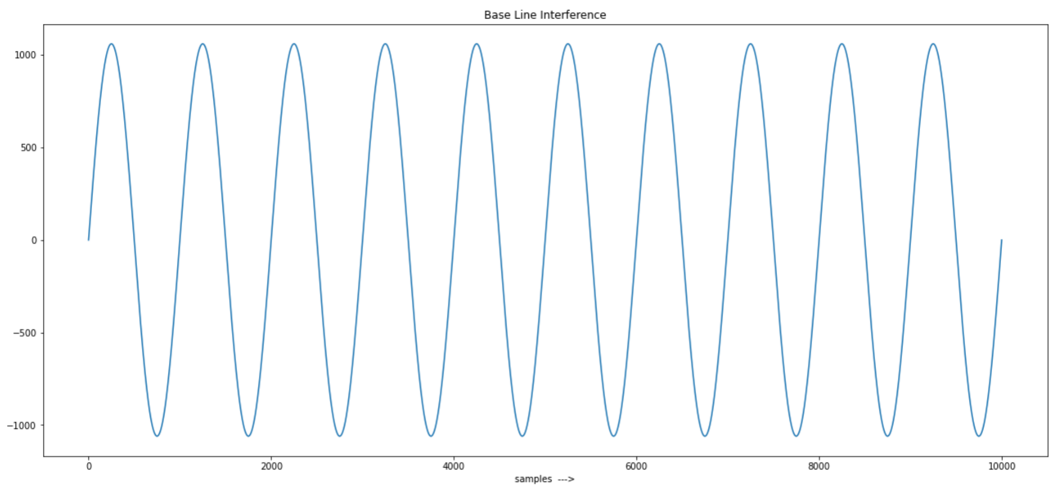
Table 1: Comparing the filters using PRD

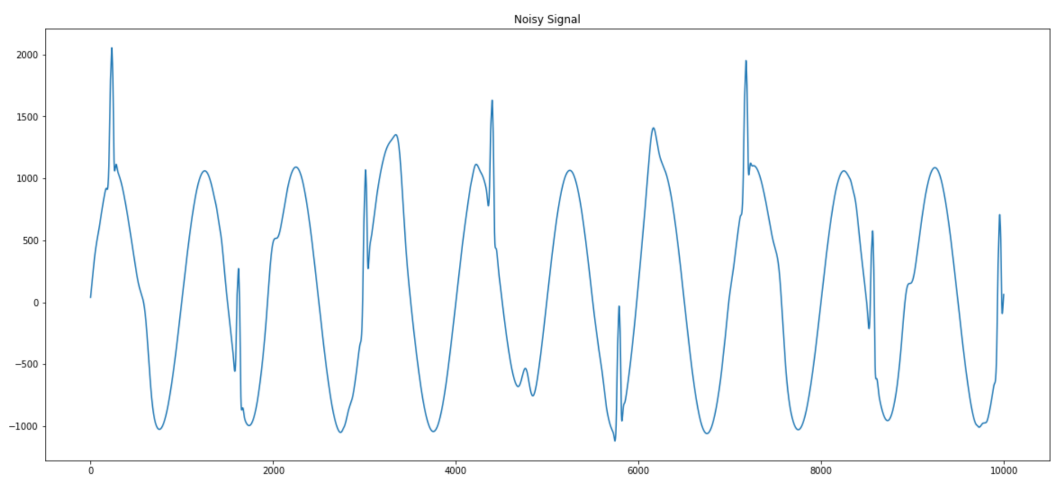
Filter	PRD
IIR notch	4.49
Mean Median	3.8

5.2 Baseline Drift

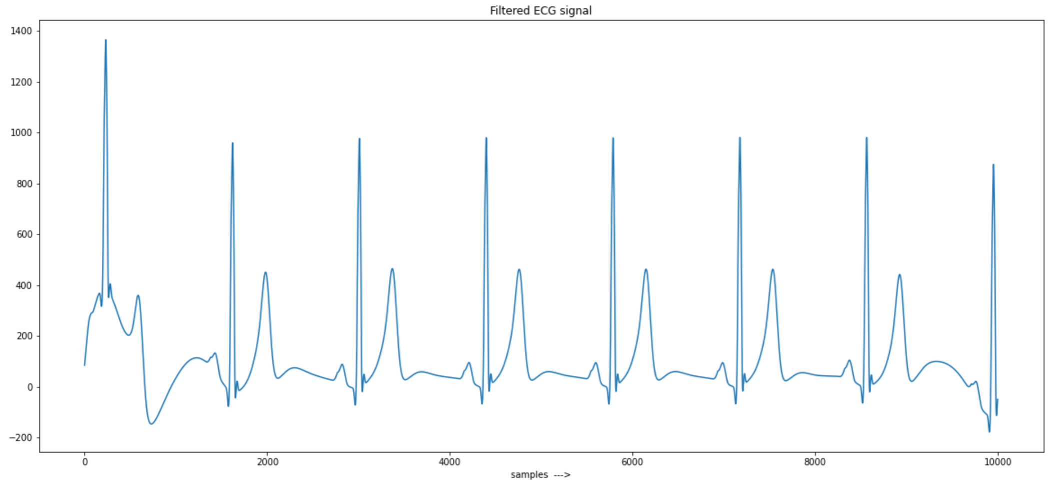
Low-frequency artifacts and base-line drift may be caused in chest-lead ECG signals by coughing or breathing with large movement of the chest, or when an arm or leg is moved in the case of limb-lead ECG acquisition. The EGG is a common source of artifact in chest-lead ECG. Poor contact and polarization of the electrodes may also cause low-frequency artifacts. Base-line drift may sometimes be caused by variations in temperature and bias in the instrumentation and amplifiers as well.

Here,we are using a sinusoidal 1Hz signal as baseline drift and adding it to the ECG signal.

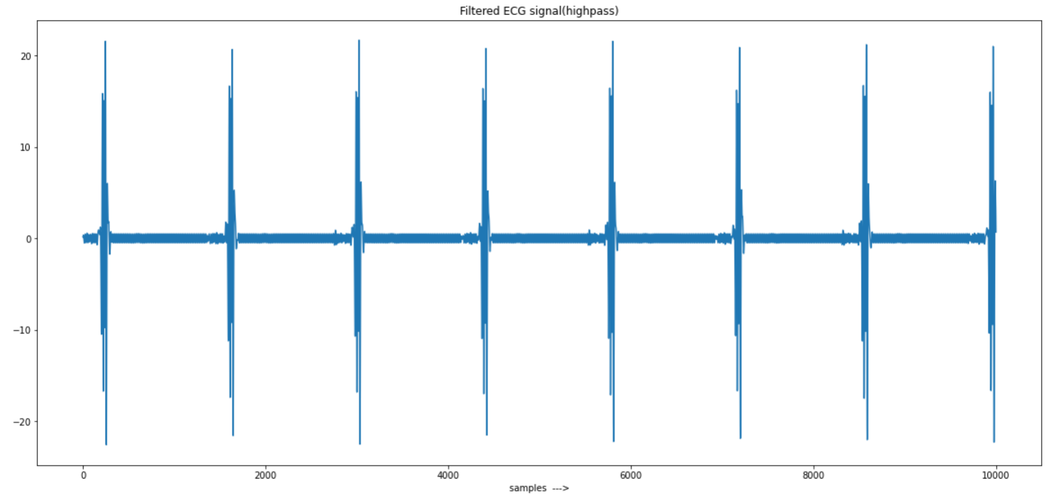




Here,the first filter used is IIR notch filter which removes a particular frequency while the others are not disturbed.It is a frequency domain filter used to remove a particular frequency.



Here,Highpass filter is used as the base line wander noise is low pass.The filter function used is from heartpy library



The notch filter used here is from the heartpy library.

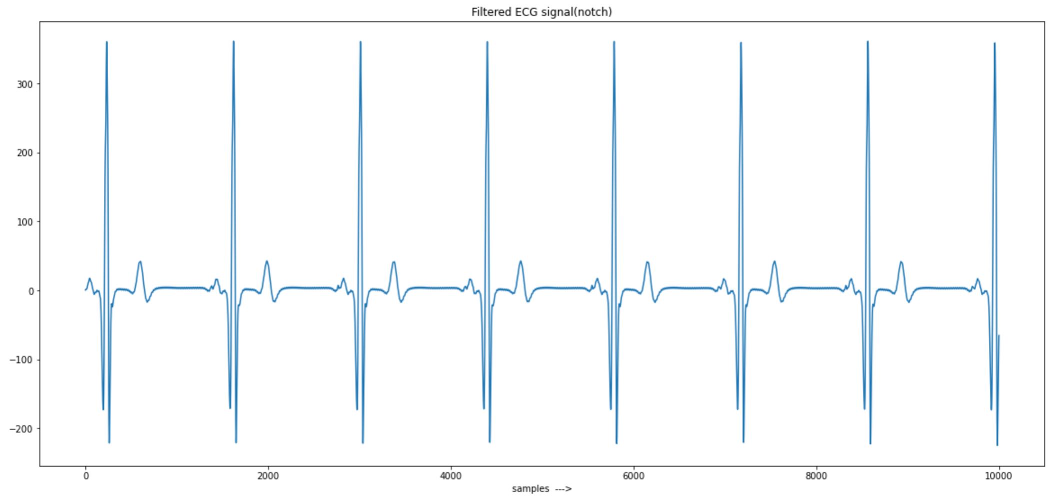


Table 2: Comparing the filters using PRD

Filter	PRD
IIR notch	3.85
Highpass	9.9
Notch	7.65

5.3 Discrete Fourier Transform (DFT)

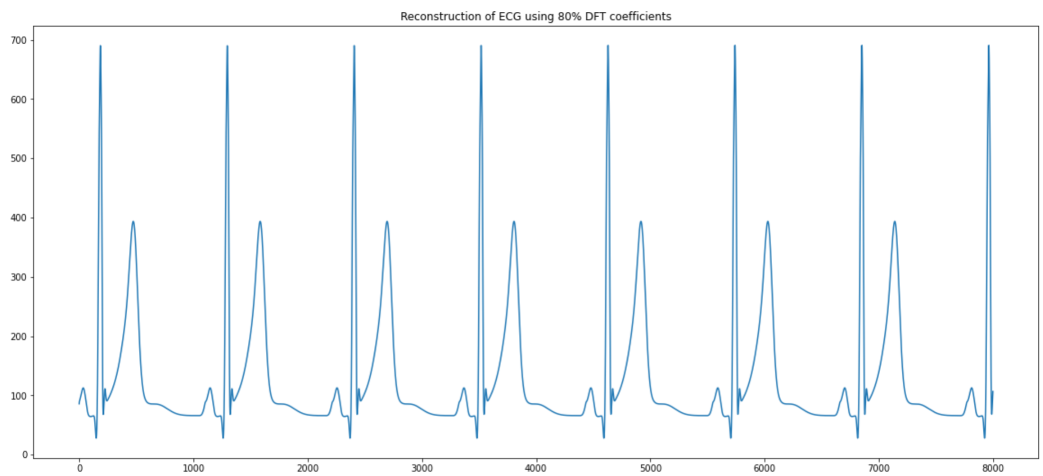
Like continuous time signal Fourier transform, discrete time Fourier Transform can be used to represent a discrete sequence into its equivalent frequency domain representation and LTI discrete time system and develop various computational algorithms.
DFT:

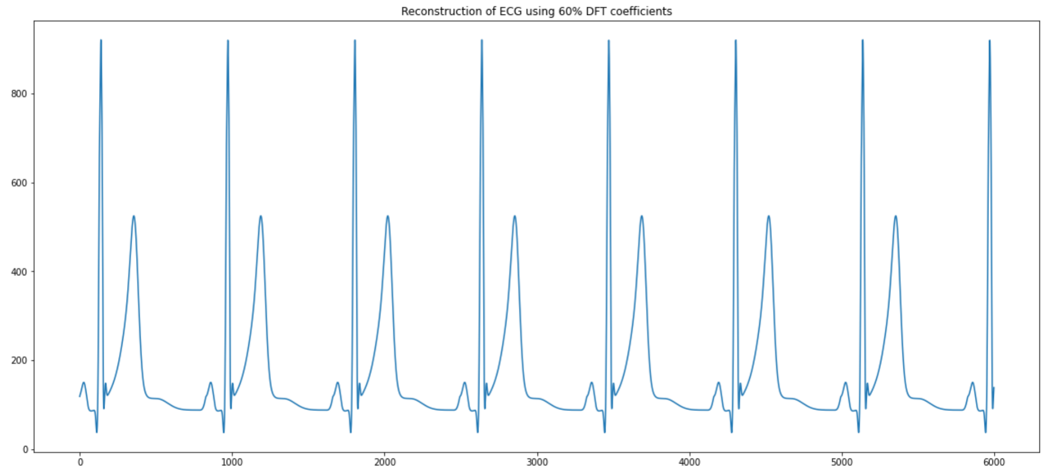
$$x[n] = \sum_{k=0}^{N-1} X(k) * e^{-j(2*pi/N)kn} \tag{2}$$

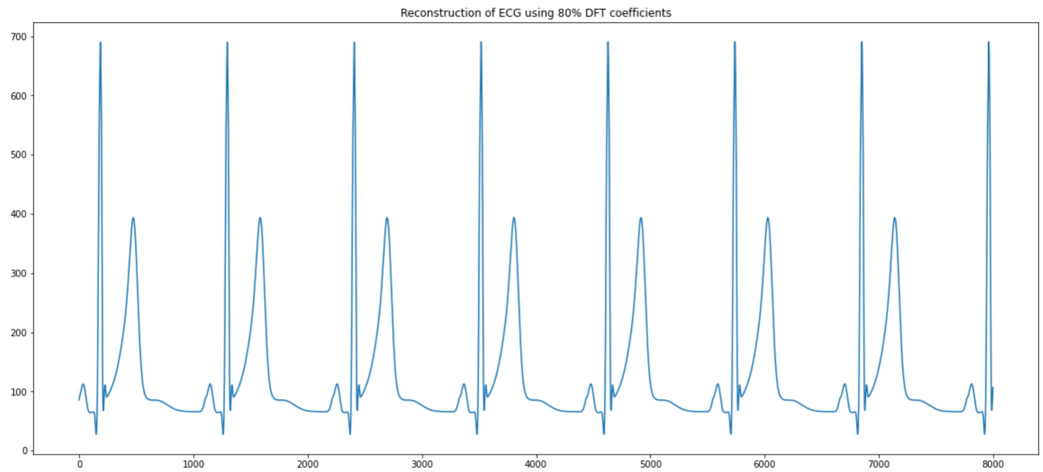
Inverse DFT:

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X(k) * e^{j(2*pi/N)kn} \tag{3}$$

Now the ecg signal is reconstructed using 80







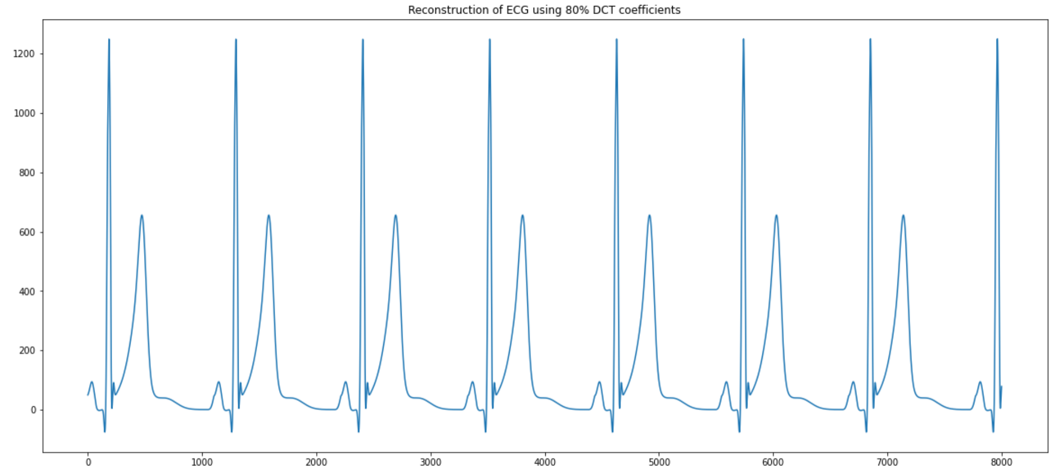
5.4 Discrete Cosine Transform (DCT)

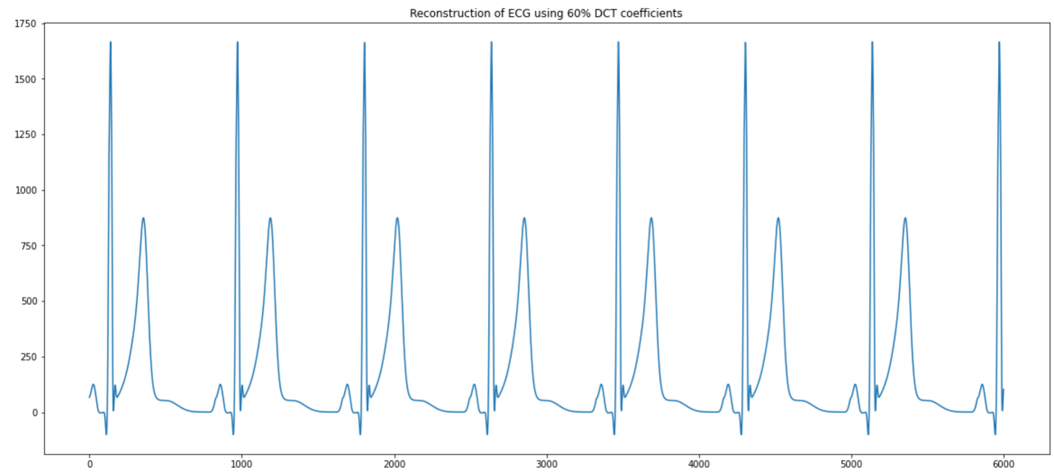
A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. Like any Fourier-related transform, discrete cosine transforms (DCTs) express a function or a signal in terms of a sum of sinusoids with different frequencies and amplitudes. Like the discrete Fourier transform (DFT), a DCT operates on a function at a finite number of discrete data points. The obvious distinction between a DCT and a DFT is that the former uses only cosine functions, while the latter uses both cosines and sines (in the form of complex exponentials). However, this visible difference is merely a consequence of a deeper distinction: a DCT implies different boundary conditions from the DFT or other related transforms.
DCT:

$$X(m) = \sqrt{\frac{2}{N}} \sum_{n=0}^{N-1} x[n] c_m cos[\frac{pi * m}{2N}(2n+1)] \tag{4}$$

Inverse DCT:

$$x[n] = \sqrt{\frac{2}{N}} \sum_{m=0}^{N-1} X(m) c_m cos[\frac{pi * m}{2N}(2n+1)] \tag{5}$$





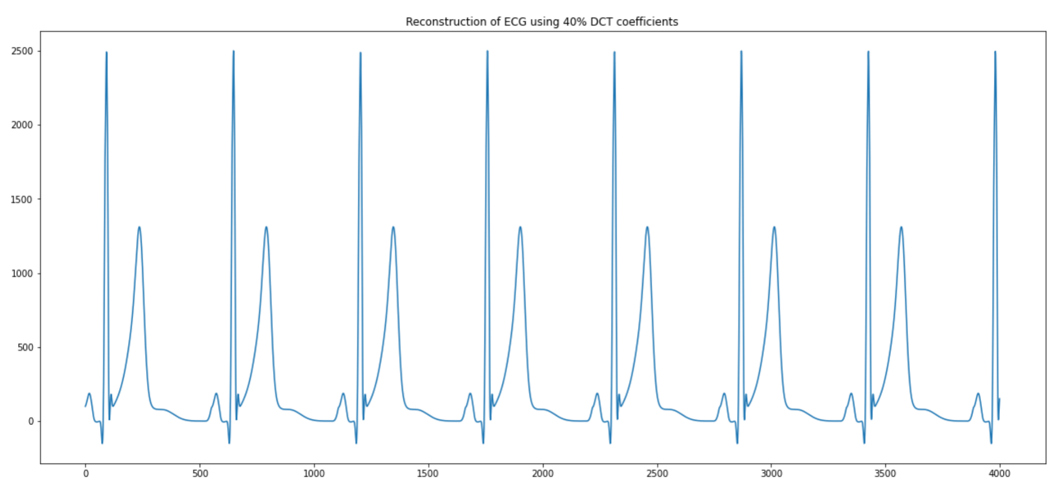


Table 3: Comparison of DCT and DFT reconstructed signal

Coeff percentage	Energy of DFT reconstructed	Energy of DCT reconstructed
40	138093020	552197223
60	184120447	736262964
80	276177233	1104394444

6 Conclusion

We can conclude that which is the best filter for the removal of the power line interference and base line drift noise using the table that gives the prd value of the respective filters.For power line interference the best filter is Mean median filter and for base line drift the best filter is IIR notch filter as they have the least prd values. The reconstruction of the signal using the DFT and DCT transforms gives us the idea of which has the higher data compression.The energy of the reconstructed signals is tabulated and the respective energies of the DCT reconstructed signal is more than the DFT reconstructed signal.The higher energy of DCT reconstructed signal shows that it is more compressible and reconstructed signal retains the energy.