POWERLINE INTERFERENCE REDUCTION IN ECG SIGNALS

KARAMJIT SINGH BEDI

102006179 3ECE4 UEC502

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INFINITE IMPULSE RESPONSE FILTERS

- IIR filters are linear time-invariant systems with an impulse response that does not become zero past a certain point, but continues indefinitely.
- In practice, their impulse response usually approaches zero and can be neglected past a certain point. This is in contrast to an FIR filter, in which the impulse response becomes exactly zero.
- The physical systems which give rise to IIR or FIR responses are dissimilar, and therein lies the importance of the distinction.
- The main disadvantage of IIR filters is that they are difficult to design, mainly when the requirement is not usual (high-pass, low-pass, notch). FIR filters can easily be designed to have a linear phase. Another issue regarding IIR filters is the potential for limit cycle behavior when idle due to feedback system in conjunction with quantization.

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PROPERTIES

1. IIR filters require less computation and memory
2. Fewer parameters are needed to achieve a sharp cut-off filter
3. Have lower filter orders than corresponding FIR filters
4. Non-linear in nature

$$H(z) = \frac{\sum_{i=0}^{P} b_i z^{-i}}{1 + \sum_{j=0}^{Q} a_j z^{-j}}$$

ELECTROCARDIOGRAM SIGNALS

- Electrocardiogram is a graph of voltage versus time of the heart's electrical activity using electrodes placed on the skin. These electrodes detect the small electrical changes that result from cardiac muscle depolarization - repolarization during each cardiac cycle.

- The overall goal of performing an ECG is to obtain information about the electrical functioning of the heart. Medical uses for this information are varied and often need to be combined with knowledge of the structure of the heart and physical examinations signs to be interpreted.

- Changes in the regular ECG pattern occur in numerous cardiac abnormalities, including cardiac rhythm disturbances, inadequate coronary artery blood flow and electrolyte disturbances.

Powerline Interference and Notch Filters

- Powerline Inteference is one of the most disturbing noise sources that hamper the analysis of ECG signals.

- Powerline Noise is most often caused by a spark or arcing across some powerline-related hardware. A breakdown and ionization of air occur, and current flows between two conductors in a gap. The gap may be caused by broken, improperly installed or loose hardware. Typical culprits include insufficient and inadequate hardware spacing.

- Notch filters highly attenuate or eliminate a particular frequency component from the input signal spectrum while leaving the amplitude of the other frequencies relatively unchanged. Thus, they behave as bandstop filters with a narrow stop band and two passbands

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- In situations where the linearity of phase is unimportant, IIR filters are preferred since these require much lower order than FIR filters with the same magnitude response specifications. Besides many other fields, Notch filters are used in biomedical engineering to eliminate noise and powerline interferences

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PROPOSED SOLUTION

- IIR Notch filters using Butterworth, Chebyshev types 1 and 2, Elliptic and Bessel techniques were designed to eliminate the noise from the ECG signal, and their outputs were compared. The different IIR filters gave satisfactory outputs in removing the Powerline Inteference

- ALGORITHM

1. The input ECG signal is visualised
2. The type of IIR filter and its specifications are given as input
3. The Frequency response of the digital filter is calculated
4. The input ECG signal is filtered and its Powerline Noise is eliminated

```
clc;
clearvars;
close all;

% input ECG signal
dir = "ECG.txt";
ecg = load(dir);
N = length(ecg);

% specifications of the digital IIR filter
disp("TYPES OF IIR FILTERS");
disp("1. BUTTERWORTH FILTER");
disp("2. CHEBYSHEV - 1 FILTER");
disp("3. CHEBYSHEV - 2 FILTER");
disp("4. ELLIPTIC FILTER");
iir = input("\nCHOOSE THE FILTER : ");
if iir > 4
   disp("INVALID INPUT!");
   return
end
order = input("FILTER ORDER : ");
lowerFc = input("LOWER CUTOFF FREQUENCY : ");
higherFc = input("HIGHER CUTOFF FREQUENCY : ");

% designing the IIR filter
switch(iir)
   case 1
       [b, a] = butter(order/2, [lowerFc, higherFc], "stop");
   case 2
       passbandRipple = input("PASSBAND RIPPLE : ");
       [b, a] = cheby1(order/2, passbandRipple, [lowerFc, higherFc],
"stop");
   case 3
       stopbandAttenuation = input("STOPBAND ATTENUATION : ");
       [b, a] = cheby2(order/2, stopbandAttenuation, [lowerFc,
higherFc], "stop");
   case 4
       passbandRipple = input("PASSBAND RIPPLE : ");
       stopbandAttenuation = input("STOPBAND ATTENUATION : ");
       [b, a] = ellip(order/2, passbandRipple, stopbandAttenuation,
[lowerFc, higherFc], "stop");
end

% spectral analysis of the IIR filter
[H, w] = freqz(b, a, N);
```

```
norm_H = abs(H)./max(abs(H));
norm_w = w./(2*pi);
subplot(1, 2, 1);
plot(norm_w, 20*log10(norm_H));
title("SPECTRAL ANALYSIS");
xlabel("NORMALISED ANGULAR FREQUENCY");
ylabel("NORMALISED FREQUENCY RESPONSE");

% eliminating noise from the signal
filtered_ecg = filter(b, a, ecg);
subplot(1, 2, 2);
plot(ecg);
hold on;
plot(filtered_ecg);
title("ECG SIGNAL");
ylabel("AMPLITUDE");
xlabel("SAMPLES");
legend("NOISY ECG SIGNAL", "FILTERED ECG SIGNAL");
```

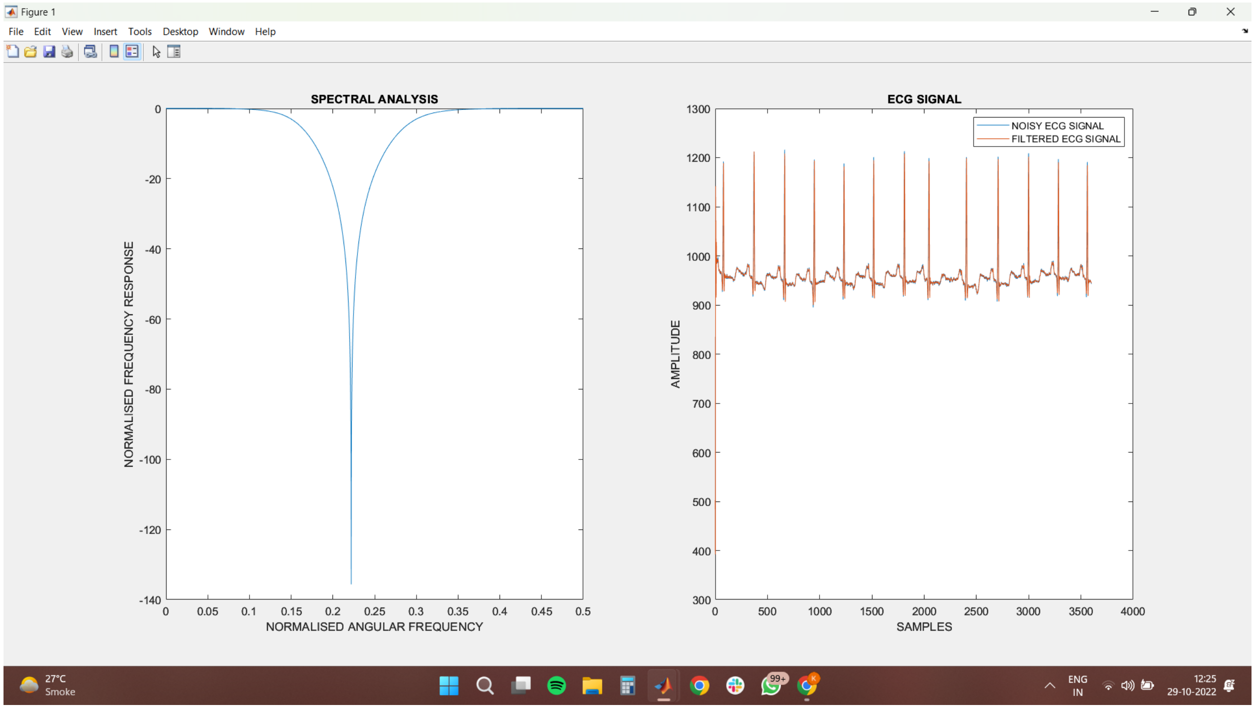
➔ HYPERPARAMETERS

- Filter Order = 4
- Lower Cutoff Frequency = 0.3π rad/sample
- Upper Cutoff Frequency = 0.6π rad/sample
- Passband Ripple = 6 dB
- Stopband Attenuation = 60 dB

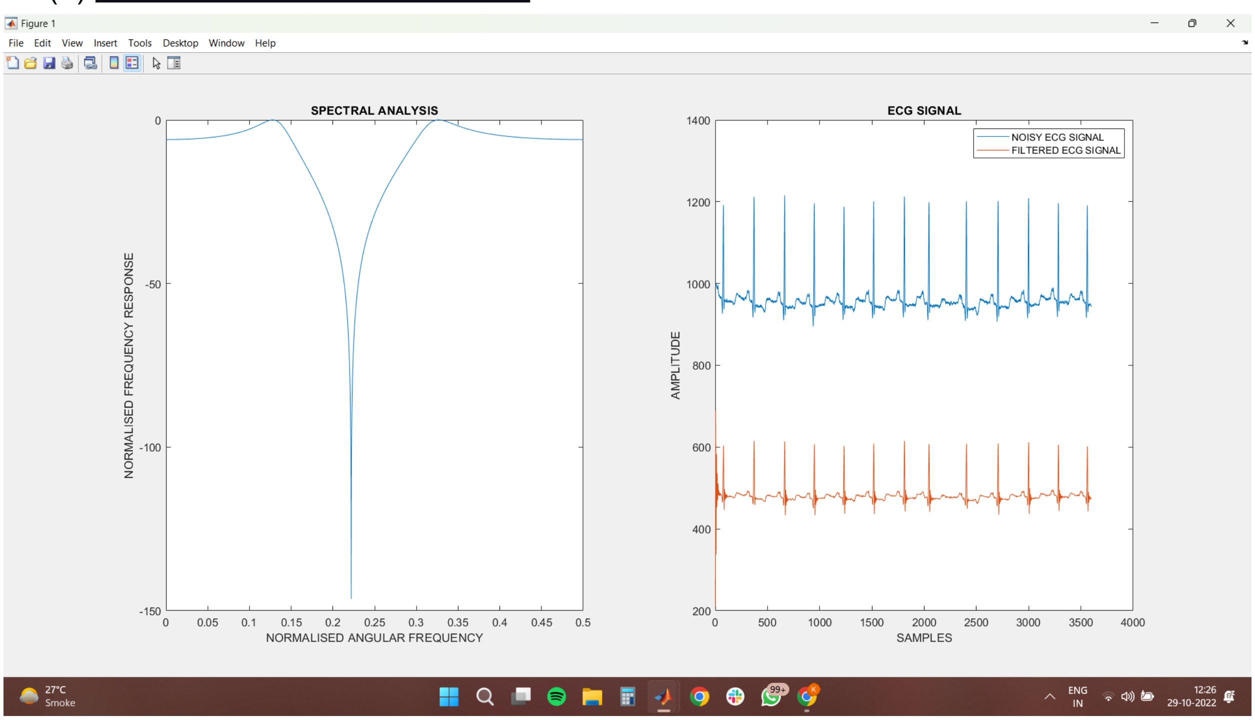
➔ RESULTS

- We notice that, for the chosen set of hyperparameters, the Chebyshev Type-1 and Elliptic filters produce the cleanest ECG signals
- However, for higher orders, we find that the Chebyshev Type-2 filter performs better

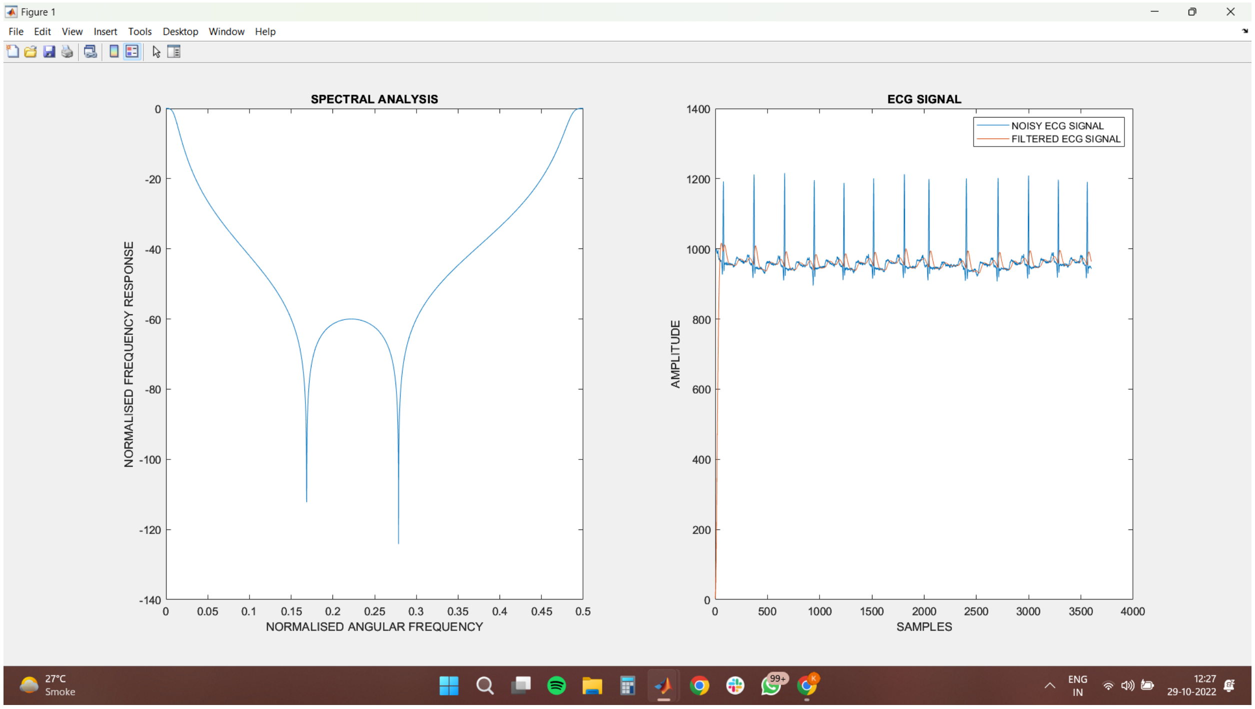
(1) BUTTERWORTH FILTER



(2) CHEBYSHEV TYPE-1 FILTER



(3) CHEBYSHEV TYPE-2 FILTER



(4) ELLIPTIC FILTER