LBYEC4A – EK1

Signals, Spectra and Signal Processing Laboratory

Final Project Proposal

Comparison of Digital Filters in Denoising Electrocardiogram Signals using MATLAB

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PROJECT DESCRIPTION

- **Background**
  - **ECG:** An Electrocardiogram (ECG) is a medical device that monitors the electrical activity of the heart using nodes placed all over the body. It tracks the spontaneous depolarization (SD) wave of the heart's SA node. The deflection waves are categorized using segments, waves, and intervals. The ECG signal's actual deflection is represented by the wave, while its segment and interval are defined by the straight line that separates them. P-waves denote the atria's depolarization, while T-waves denote the ventricles' repolarization. The three waves of the QRS complex, Q, R, and T, stand in for the depolarization of the ventricles. The negative-positive-negative deflection that is tightly packed in an ECG signal is known as the QRS complex [1]. The deflections visible in the ECG graph are caused by the SD flow through the carefully positioned nodes on the body [2]. However, the nodes are susceptible to interference from various factors, and corresponding frequency ranges where the noises/interference can be found exist.

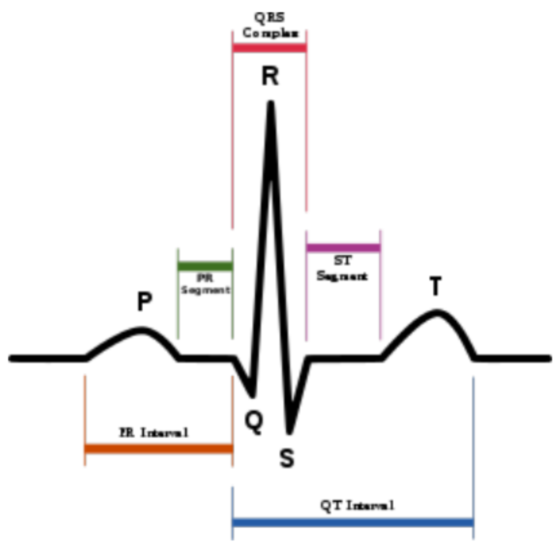


Figure 1: ECG Signal at a Time Interval [3]

  - **NOISE IN ECG:**
    - Several external influences that influence the electrical nodes distributed throughout the body can be blamed for noise or interference in an ECG signal. Low- and high-frequency interference are two subcategories of these noises. Baseline wander (BW) is a type of low-frequency interference which happens when the impedance between the electrodes and the patient's skin, breathing, or

movement is incorrect. The ECG signal is impacted by baseline wander when the baseline is not steady and is moved upward. This interference frequently happens around 0.5-0.6 Hz, and their frequency rises with movement. On the other hand, Powerline interference and Electromyogram (EMG) noise are examples of high-frequency interference. When a powerline is situated close to the subject, powerline interference (PLI) happens. The frequency range of this noise is between 50 and 60 Hz. When muscle electrical activity outside of the heart is detected by the nodes, EMG noise results. These often happen when there is patient movement, and occurs at frequencies greater than 100 Hz [3].

- **DIGITAL FILTERS:** A digital filter uses a digital processor to perform numerical calculations on sampled values of the signal. The processor may be a general-purpose computer such as a PC, or a specialized DSP (Digital Signal Processor) chip.
    - **Low-pass filter -** A low-pass filter (LPF) is a circuit that only passes signals below its cutoff frequency while attenuating all signals above it. It is the complement of a high-pass filter, which only passes signals above its cutoff frequency and attenuates all signals below it. It has applications in anti-aliasing, reconstruction, and speech processing, and can be used in audio amplifiers, equalizers, and speakers.
    - **FIR filter -** a filter whose impulse response is of finite period, as a result of it settles to zero in finite time. This is often in distinction to IIR filters, which can have internal feedback and will still respond indefinitely. The impulse response of an Nth order discrete time FIR filter takes precisely N+1 samples before it then settles to zero. FIR filters are the most popular kind of filters executed in software and these filters can be continuous time, analog or digital and discrete time.
    - **IIR Filter**
        - **Butterworth filter -** a filter associated with the passband region having a frequency response that is flat. Ideally, the order of the butterworth determines the frequency response of filter design, a higher order will have a steeper roll-off region which when further cascaded will have an increase in the order will resemble more the brick-type ideal frequency response of the filter. [4]
        - **Chebyshev Types I and II filters -** filter designs that have steeper roll-off as compared to that of the Butterworth filter.

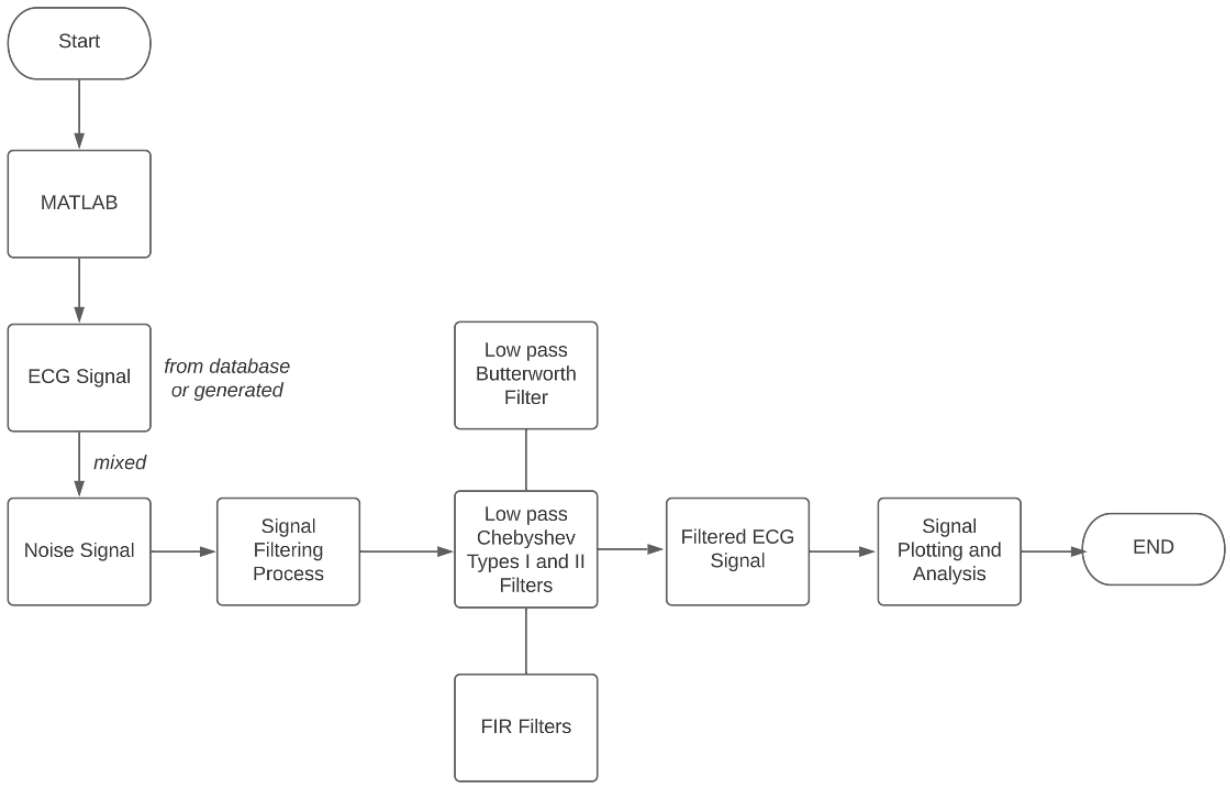
Because of this steeper roll-off it has a ripple on either the passband region or in the attenuation region or the stopband region. The downside of Chebyshev filters is the ripples in the passband, which increases the error between idealized and real filter characteristics along the range of filters. [4]

- **Objectives:**
    - This project aims to create the following features:
        - Utilize a number of analog and digital filters
        - Determine the differences of the two filter types
        - Discover the most effective filter for denoising ECG signals.

METHODOLOGY

- Signal Sources
    - ECG Database
    - Noise Application
        - High Frequency Noise
            - Electromyogram : >100 Hz
        - Mid Frequency Noise
            - Powerline interference 50-60 Hz
        - Low Frequency Noise
            - Baseline Wander: 0.5 Hz
        - Random Signal
- Application of Filter
    - MATLAB Software
        - Type of Filter and How they are applied
- Comparison Of Results
    - Mean Square Error: $MSE = \frac{\Sigma(s-\hat{s})^2}{N}$
    - Signal-to-Noise Ratio: $SNR_{dB} = 10log_{10}(\frac{S}{N})_P$
    - Correlation of Denoised Signal to Original Signal: $r_{xy}(\tau) = \int_{-\infty}^{\infty} x(t) \cdot y(t-\tau)\mathrm{d}t$ [6]

- Flowchart



SCHEDULE OF ACTIVITIES

TASK/DELIVERABLES	DATE OF SUBMISSION
Final Project Proposal	March 13, 2023
Final Project Review	March 27, 2023
Project Demo	April 10, 2023

REFERENCES

[1] L. Potter, “Understanding an ECG: ECG interpretation,” Geeky Medics, 12-Nov-2021. [Online]. Available: https://geekymedics.com/understanding-an-ecg/. [Accessed: 13-Mar-2023].

[2] D. Price, “How to read an electrocardiogram (ECG). part One: Basic principles of the ECG. the normal ECG,” South Sudan Medical Journal. [Online]. Available: http://www.southsudanmedicaljournal.com/archive/may-2010/how-to-read-an-electrocardiogram-ecg.-part-one-basic-principles-of-the-ecg.-the-normal-ecg.html. [Accessed: 13-Mar-2023].

[3] R. Kher, “Signal Processing Techniques for Removing Noice from ECG Signals,” J Biomed Eng 1: 1-9. [Accessed: 01-May-2022].

[4] Rastogi, N., & Mehra, R. (2013). Analysis of butterworth and Chebyshev filters for ECG Denoising Using Wavelets. Retrieved July 6, 2022, from https://iosrjournals.org/iosr-jece/papers/Vol6-Issue6/G0663744.pdf

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