ISLAMIC UNIVERSITY OF TECHNOLOGY

Project Report: Advanced Techniques in Biomedical Signal Processing Lab

Project Title: Electrocardiogram Signal Denoising and Wiener Filtering Using Different Desired/Optimal Signals

Group Members:

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Introduction

Background and Significance

Electrocardiography (ECG) is a critical diagnostic tool that measures the electrical activity of the heart. However, ECG signals are vulnerable to several types of noise, such as power line interference, baseline drift, and muscle artifacts, which can significantly compromise their diagnostic value. Hence, effective denoising is crucial for accurate clinical interpretation. This project explores the use of statistical techniques, such as Wiener filtering, and optimal signal processing methods to enhance the signal quality, enabling precise diagnostic assessment.

Objective and Scope

1.Implement Wiener filtering techniques to remove artifacts by leveraging the statistical properties of ECG signals.

2. Employ synchronous averaging to improve signal-to-noise ratio (SNR).

3. Apply moving average filters of varying lengths to achieve signal smoothing.

4. Detect QRS complexes by applying cross-correlation functions and setting appropriate thresholds.

Methodology and Implementation

1. <u>Synchronous Averaging:</u>

This process involves averaging multiple instances of the ECG signal to minimize the impact of random noise while retaining significant signal components. White noise is normally distributed with a mean value near zero. Therefore, averaging ensures that noise has a diminished effect on the resultant signal.

Several noisy ECG signals were averaged in a time-synchronous manner, thus significantly improving the SNR.

2. <u>QRS Complex Detection with Cross-Correlation:</u>

QRS complex detection is critical in analyzing ECG data. A QRS complex from the signal was selected as a template, and cross-correlation was used to compare it against other regions of the signal. The correlation coefficient, ranging from -1.0 to +1.0, indicates the similarity between the template and subsequent signal regions.

Cross-correlation functions were calculated between the QRS complex template and the rest of the ECG signal. Peaks in the correlation coefficient indicated the presence of a similar QRS complex, allowing for accurate identification.

3. Moving Average Filters:

The moving average (MA) filter calculates the arithmetic mean of a specific number of preceding points within the signal. It is an effective smoothing method that reduces high-frequency noise while maintaining overall signal structure.

Moving averages of 2-point and 4-point window sizes were computed. A 2-point MA provided modest smoothing, while the 4-point MA delivered more significant noise reduction at the expense of some signal detail.

4. Wiener Filtering:

Wiener filtering is a statistical technique that minimizes the mean square error between the filtered output and a desired reference signal. It utilizes the Wiener-Hopf equation to determine optimal filter coefficients.

The Wiener filter was designed using known ECG signal statistical properties to remove artifacts. The filter minimized the difference between the filtered output and a desired reference signal.

Results

1. Synchronous Averaging:

Synchronous averaging proved to be effective in significantly reducing random noise without compromising the integrity of the primary signal. The SNR was markedly improved.

2. QRS Complex Detection:

Cross-correlation analysis facilitated accurate detection of QRS complexes, enabling precise identification of critical heart activity markers.

3. Moving Average Filters:

The moving average filters successfully smoothed out the ECG signal, with the 4-point MA providing superior noise reduction. However, the 4-point window also led to some loss of detail in the signal morphology.

4. Wiener Filtering:

Wiener filtering effectively removed signal artifacts and clarified ECG data, enabling more accurate diagnostic interpretation. This method demonstrated particular utility in addressing noise sources that are statistically different from the desired signal.

Conclusion

Through the comprehensive application of synchronous averaging, moving averages, and Wiener filtering, the project significantly enhanced the quality of ECG signals. Synchronous averaging minimized the impact of random noise, and the moving average filters provided adjustable levels of smoothing based on the chosen window size. The Wiener filtering technique proved adept at removing artifacts and enhancing the SNR. In combination, these methods provide a robust framework for clinical ECG signal analysis and accurate detection of QRS complexes, thus improving the reliability of diagnostic processes.

Contribution Report

Group Members and Contributions:

This project was initiated with the conceptualization and initial framework designed by Md. Faiyaz Abrar Fahim, who led the coding efforts. His vision for applying Wiener filtering and synchronous averaging to enhance ECG signal quality shaped the project’s objectives and methodologies.

Mahfuzul Islam managed the collection and preparation of ECG datasets, vital for testing signal processing techniques. He was responsible for analyzing ECG recordings affected by various types of noise, an essential task in a project centered on denoising. Also making sure the data and analysis is on track.

Redwan Ul Bari concentrated on the project's coding and technical aspects, working closely with his teammate to ensure implementation aligned with their objectives. He didn’t just code; he excelled at debugging, employing a meticulous approach to troubleshooting that ensured the algorithms were both effective and efficient.

Summary:

The project team combined their unique strengths to successfully enhance ECG signal quality. One member provided vision and coding expertise, another ensured efficient debugging, and a third managed ECG dataset collection. Together, they applied theoretical knowledge to solve practical challenges, achieving notable results and exemplifying teamwork and interdisciplinary cooperation.