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Analysis of Electromyography (EMG) Signal Processing with Filtering Techniques

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***Abstract*—The paper presents the Analysis of Electromyography (EMG) Signal Processing with Filtering Techniques. The problem in this study is how to consider the filtering techniques for fundamental EMG signal processing with high-level accuracy. The research method for designing the simulation codes for observing the EMG signal modeling and digital filtering techniques with mathematical approaches from the signals and systems concepts. The results confirm that the outcomes of this study met the performance target for noise removal techniques of EMG signals in real-world applications.**

***Index Terms*— Electromyography, EMG, Filtering Techniques, Signal Processing.**

I. INTRODUCTION

THIS EMG signals have a variety of usefulness including Clinical applications, Engineering applications, evolvable hardware chip (EHC) development, modern human-computer interaction, electrical wheelchair control, robotic applications, industrial applications, sports medicine, and occupational medicine [1-3].

One of the important processes in the described applications is the development of EMG recognition systems. The EMG recognition system consists of three cascaded modules, namely, data pre-processing, feature extraction, and classification. The main process in data pre-processing is to remove noise-contaminated EMG signals [4-7].

This work is an initial point of consideration the signal processing which was focused on developing a novel technique for detecting and removing multiple types of noise-contaminated in the EMG signal. The advantages are not only that a high-quality EMG signal can be obtained but also that a reduction in computational complexity can be achieved while still maintaining similar performance compared to the previously developed algorithm [8-12].

The paper is organized as follows. Section II mentions the Materials and Methods. Section III gives the implementation with the appropriate design of signal processing. Section IV mentions the Results and Discussions. Section V concludes the research outcomes and recommendations of the study.

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II. METHODS

Processes in the development of the EMG recognition system consist of data pre-processing, feature extraction, and classification. In the intricate realm of data pre-processing for electromyographic (EMG) signals, the paramount objective revolves around mitigating noise contamination. Fig. 1 provides a visual representation of the fundamental concepts in EMG Signal Processing [13-15]. A myriad of techniques are employed to eliminate interference, particularly from electrocardiographic (ECG) sources. Digital filters, acting as efficient gatekeepers, sift through the signal, isolating and extracting the desired EMG information. Template subtraction involves subtracting a predefined template from the signal to discern and eliminate unwanted components. The adaptive filter dynamically adjusts its parameters, tailoring its response to varying signal characteristics. Wavelet transform, with its prowess in capturing both temporal and frequency aspects, plays a pivotal role in denoising EMG signals. Moreover, the synergy of multiple techniques unveils novel strategies, such as combining digital filters with template subtraction or integrating artificial neural networks (ANN) with wavelet transform. The avant-garde approach of combining adaptive neuro-fuzzy inference systems (ANFIS) with wavelet transform showcases the continuous evolution of methods, emphasizing the perpetual pursuit of refining EMG signal processing for enhanced precision and reliability.

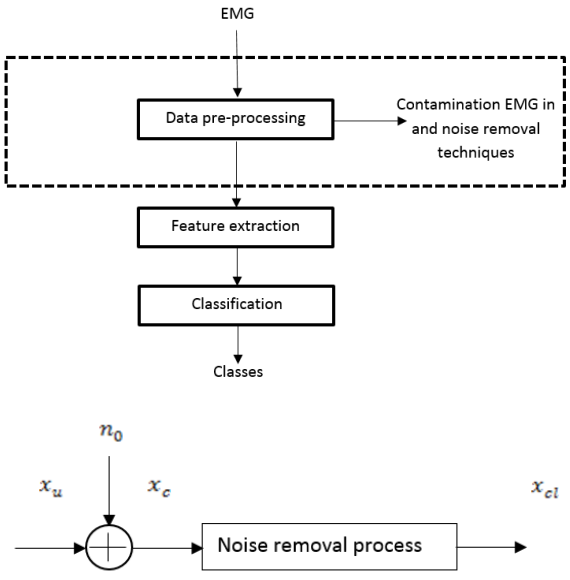


Fig.1. EMG Signal Processing Concepts

The mathematical modeling of the developed low-pass filter design could be analyzed based on the following

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governing equations.

$$H(z)=\frac{1}{\left(1-re^{j\theta}z^{-1}\right)\left(1-re^{-j\theta}z^{-1}\right)} \quad (1)$$

$$H(z)=\frac{1}{\left(1-2r\cos\theta z^{-1}+r^{2}z^{-2}\right)} \quad (2)$$

$$H_{couple}(z)=\frac{r\sin\theta z^{-1}}{\left(1-\left(r\cos\theta+jr\sin\theta\right)z^{-1}\right)\left(1-\left(r\cos\theta-jr\sin\theta\right)z^{-1}\right)} \quad (3)$$

$$H_{couple}(z)=\frac{r\sin\theta z^{-1}}{1-2r\cos\theta z^{-1}+r^{2}\left(\cos^{2}\theta+\sin^{2}\theta\right)z^{-2}} \quad (4)$$

III. Results and Discussions

A. *Processing of EMG Raw Signals with Discrete Fourier Transform Techniques*

The overlapped plot between the input signal and impulse response illustrates the y [550] output computation. The overlapped section represents the convolution sum operation with multiplication and accumulation. Assume that the future data is not accessible to maintain the causality of the system. Fig. 2 shows Result 1 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques.

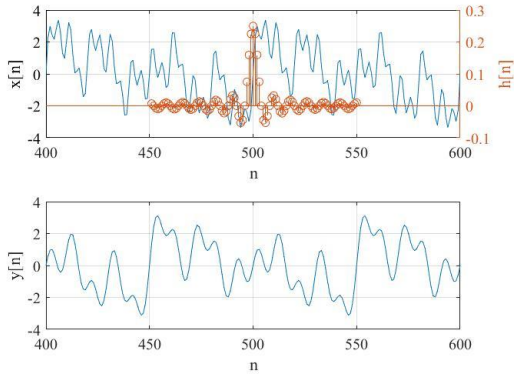


Fig. 2. Result 1 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques

The overlapped plot between the input signal and impulse response illustrates the y[509] output computation. The x[509] and the previous 19 data are involved in computing the output y[509]. Also, the output is delayed for 9 samples due to the impulse response shift. Fig. 3 demonstrates Result 2 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques.

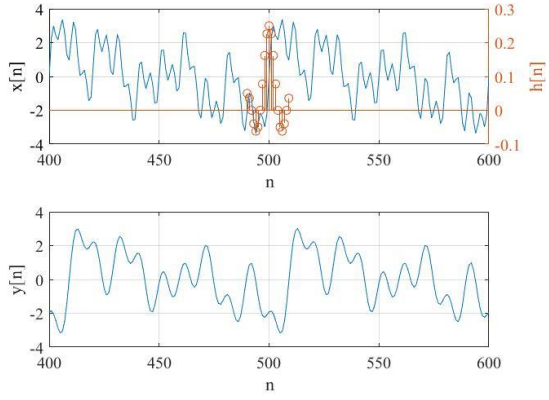


Fig. 3. Result 2 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques

The input signal with 100 sample periods containing the even 100, 50, 25, 20, 10, and 5 sample period signal components. The output for the selected range is presented. Note that the output is part of the stream outcome without any transition introduced by the incomplete overlapped convolution sum. The transitions generally appear at the time edges of the input signal such as start and end time. Fig. 4 shows Result 3 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques.

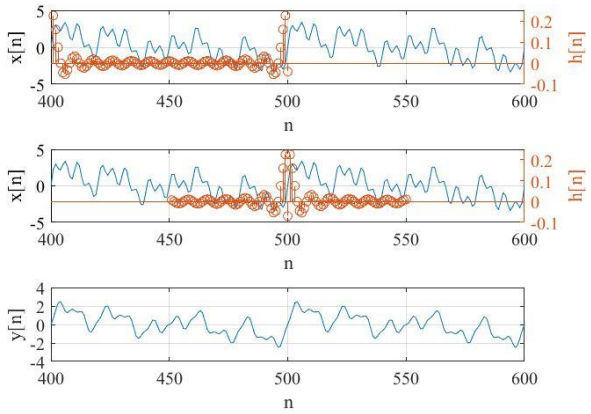


Fig. 4. Result 3 of the Processing of EMG Raw Signals with Discrete Fourier Transform Techniques

B. *LPF output with 100 and 20-length impulse response for Raw EMG Signals*

If the short impulse response works properly, there is no need to increase the impulse response since the length costs the computation and memory of the system. According to the above filter outputs, short impulse response performs the specified LPF function well. Fig. 5 shows the Results for LPF output with 100 and 20-length impulse responses for Raw EMG Signals.

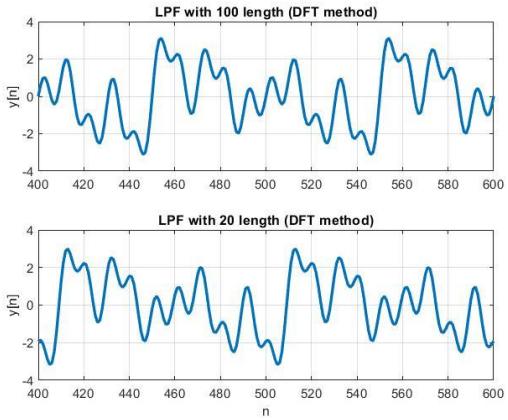


Fig. 5. Results for LPF output with 100 and 20 length impulse response for Raw EMG Signals

1. Shifted impulse response and corresponding frequency response in magnitude for Raw EMG Signals

Below the $\pi/4$ radian frequency components are propagated through the filter without losing the Raw EMG signal magnitude at all. On the other side, above the $\pi/4$ radian frequency components are completely blocked by

the filter because of zero magnitudes in frequency response. No fluctuations are observed in the passing and blocking frequency band in the frequency response. Fig. 6 illustrates the Results for Shifted impulse response and corresponding frequency response in magnitude for Raw EMG Signals.

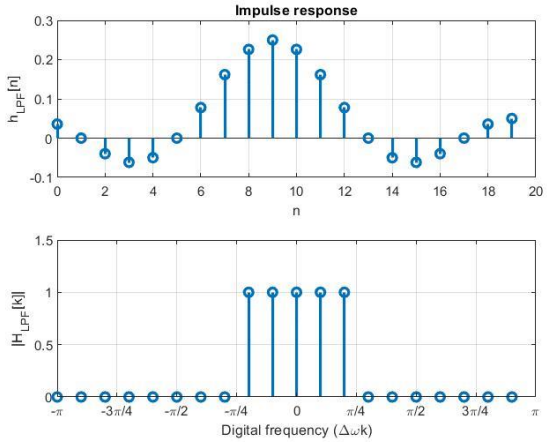


Fig. 6. Results for Shifted impulse response and corresponding frequency response in magnitude for Raw EMG Signals

2. LPF impulse response and corresponding frequency response based on the DFT (discrete) and DTFT (continuous) for Raw EMG Signals

The continuous and discrete plots represent the DTFT and DFT analysis, respectively. The continuous frequency response from the DTFT denotes the ripples in the passing and blocking bands in the frequency domain. The discrete frequency response samples the ideal locations from the continuous counterpart to pretend the perfect response of LPF. Fig. 7 illustrates the Results for LPF impulse response and corresponding frequency response based on the DFT (discrete) and DTFT (continuous) for Raw EMG Signals.

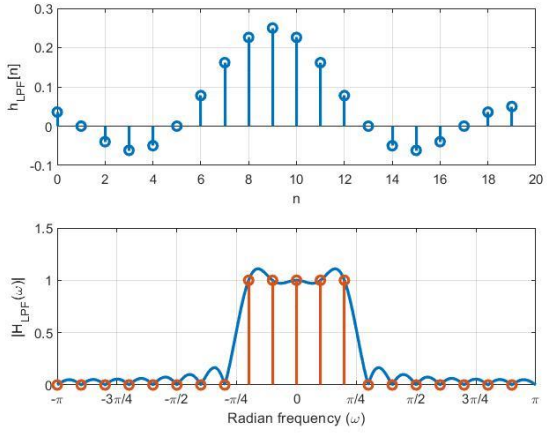


Fig. 7. Results for LPF impulse response and corresponding frequency response based on the DFT (discrete) and DTFT (continuous) for Raw EMG Signals

3. 20 length DFT of input x[n] and output y[n] from 20 length LPF for Raw EMG Signals

The output EMG signal from the LPF perfectly maintains or removes the passing and blocking band EMG signal in the filter output. Only the zero, $\pi/10$, and $\pi/5$ radian frequencies survived the LPF processing without changing the Raw EMG signal magnitude at all. The other frequencies are eliminated and barely seen in the output frequency profile. This result contributes to the ideal condition that the Raw EMG signal period is equal to the DFT LPF length. Fig. 8 shows the Results for 20-length DFT of input x[n] and output y[n] from 20-length LPF for Raw EMG Signals.

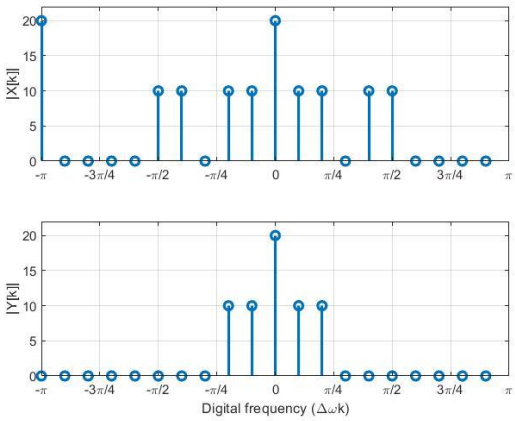


Fig. 8. Results for 20-length DFT of input x[n] and output y[n] from 20-length LPF for Raw EMG Signals

C. Filter Implementation Components Analysis

The pole locations are important to specify the pass frequency band; therefore, the poles should be placed at precise positions. The quadratic equation in the denominator is characterized by the quantized coefficients with binary fraction numbers. The roots of the equation demonstrate the limited numbers and pole distributions due to the constrained numeric system. Fig. 9 demonstrates the Results of the Filter Implementation Components Analysis.

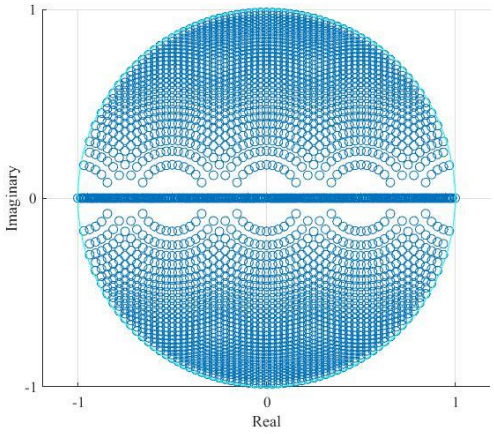


Fig. 9. Results for Filter Implementation Components Analysis

1. Frame-based Processing for EMG Signals for Input and Filtered Output (Function)

The EMG Signals for input to observe the filtered output in frame-based processing could be implemented with function creation approaches. The input signal of the EMG signal is the walking condition of a human being in a random mode. The output signal after the filtering process for that EMG signal could be captured by the coupled system functions that are indicated in various pole locations of the filter design. Fig.10 shows the Results of Frame-based Processing for EMG Signals for Input and Filtered Output (Function).

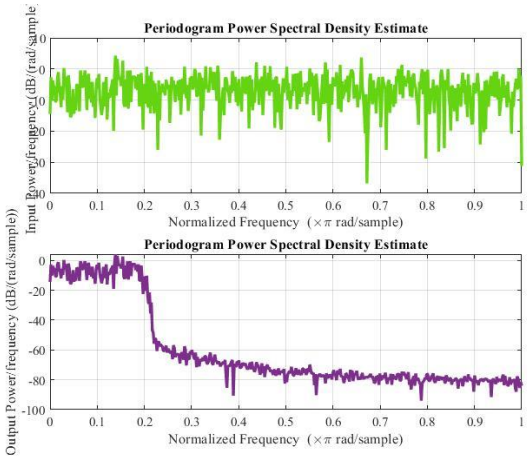


Fig. 10. Results for Frame-based Processing for EMG Signals for Input and Filtered Output (Function)

2. Frame-based Processing for EMG Signals for Input and Filtered Output (Object)

The EMG Signals for input to observe the filtered output in frame-based processing could be implemented with object-based creation approaches. The same input signal of the EMG signal as the output signal after the filtering process for that EMG signal could be observed in the coupled system functions that are indicated in various pole locations of the filter design. The value of normalized frequencies is a little bit different because of the analysis model. Fig. 11 mentions the Results of Frame-based Processing for EMG Signals for Input and Filtered Output (Object).

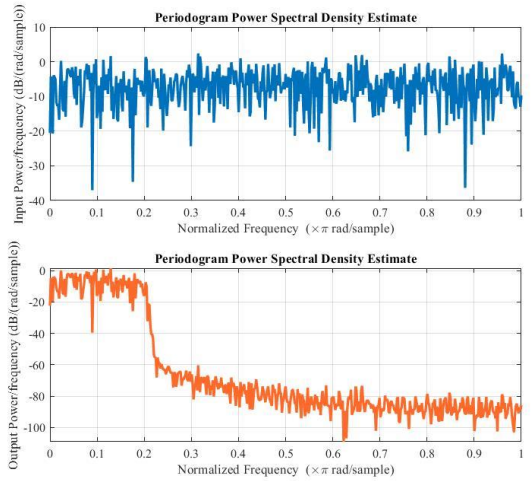


Fig. 11. Results for Frame-based Processing for EMG Signals for Input and Filtered Output (Object)

V. Conclusion

According to the literature review, there are four types of noise-contaminated in the EMG signal, namely, ECG interference, power line interference, motion artifact, and baseline noise. To get better accuracy and performance, so need to use suitable methods to improve it. Among them, one of the noise contaminated in the EMG signal could be analyzed. The fundamental concepts of signal processing toward the EMG signal processing could be established. The raw EMG signals were analyzed to confirm the mathematical calculation for further improvement of the system design. The Discrete Fourier Transform (DFT) technique is a powerful method for finding the optimum solution in EMG signal processing. The different sample data and sampling rates for checking the shifting of the impulse signal are very important for complex EMG signals to extract specific purposes. The data validation of the signal processing is carried out from the specific data sources in this study. The raw EMG Signals have been analyzed based on the filtering process using a basic filter design in this study. If the filter performance is insensitive to the filter length, it does not need to choose the longer filter that increases the computation time and output delay. While the discrete frequencies provide the ideal LPF response, the intermediate frequency response is unknown to the filter designer based on the given information. Therefore, the continuous frequency response is required to be investigated for further analysis.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Author Contributions

This study mainly focuses on the analysis of electromyography (EMG) signal processing with filtering techniques. The theoretical analyses on mathematical modeling for EMG signals play a vital role in enhancing high-performance Biomedical Engineering Applications for smart healthcare systems. This work could be provided to find the solution for research problems in advanced signal processing and filtering techniques under the Biomedical Engineering System design in reality.

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