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Implementation of the Process for Contamination in Electromyography (EMG) Signal by Using Noise Removal Techniques

Nandar Oo, Hla Myo Tun, Devasis Pradhan, Lei Lei Yin Win, Mya Mya Aye, Thandar Oo

***Abstract*—The paper describes the analysis of electromyography (EMG) signals using noise removal techniques. The problem in this study is to consider a noise removal technique for basic EMG signal processing by the Band Pass Filter method. A research approach to designing simulation codes for observing EMG signal modeling and noise removal techniques through mathematical methods from signals and systems concepts. The results confirm that it can provide high-performance target monitoring of the EMG signal in real-world applications.**

***Index Terms*— Biomedical Signal Processing, Digital Signal Processing, Electromyography, Filtering Techniques, Noise Removal Techniques**

I. Introduction

CLINICAL applications in EMG signals; Engineering applications, evolvable hardware chip (EHC) development; modern human-computer interaction; electronic wheelchair control; robotic applications; and industrial applications; It has a variety of uses, including sports medicine and occupational medicine. [1-3]. Electromyography (EMG) measures the muscle or electrical interaction of a human muscle in response to a nerve stimulus. The test is used to help diagnose neuromuscular abnormalities. During the test, a small needle (or electrode, as some call it) is inserted through the skin into the muscle.

Electromyography (EMG) is a process used to assess the health of muscles and to analyze the nerve cells that control motor neurons. The detection of EMG signals can be used to detect neurological dysfunction. It can indicate problems with muscle function or nerve-to-muscle signal transmission. One of the important processes in the mentioned applications is the development of EMG recognition systems. The data preprocessing in an EMG recognition system. Features extraction and classification consist of three parts. A key process in data preprocessing is to remove contaminating noise in the EMG signals [4-7].

This work is an initial consideration in signal processing focused on developing a novel technique for detecting and removing various contaminating noises in the EMG signal.

Nandar Oo, Lei Lei Yin Win, Mya Mya Aye, and **Thandar Oo** are with the Department of Electronic Engineering, Yangon Technological University, Gyogone, Insein PO, 11011, Yangon, Myanmar. **Prof. Dr. Hla Myo Tun** (corresponding author) is with the Department of Research, Yangon Technological University, Gyogone, Insein PO, 11011, Yangon, Myanmar. The corresponding author's email address is hmt.ytu@gmail.com. **Devasis Pradhan** is with the ECE Department of Acharya Institute of Technology, India.

The advantages are not only that a high-quality EMG signal can be obtained, but also that the computational complexity can be reduced while maintaining similar performance compared to the previously developed algorithm [8-12].

Involved in the development process of the EMG recognition system: pre-processing of data, extraction of the feature, and data classification. The main process of data preprocessing is to remove contaminating noise in the EMG signal. Fig. 1 illustrates EMG Signal Processing Concepts [13-16].

Several ECG interference removal techniques: Digital filter, Template subtraction, Adaptive filter, Wavelet transform, Combined techniques, Digital filter combined with template subtraction, Artificial neural network (ANN) is performed to the wavelet transform, and Adaptive neuro-fuzzy inference system (ANFIS) combined with wavelet transform.

The organization of the article is as follows. Section II presents the research direction. Section III mentions the results and discussions on the analyses. Section IV concludes the study of this work for the expected outcomes.

II. Research Method

The development process of the EMG recognition system consists of the following steps: pre-processing of data, extraction of the feature, and data classification. The main process of data preprocessing is to remove contaminating noise in the EMG signal. Figure 1 shows EMG Signal Processing.

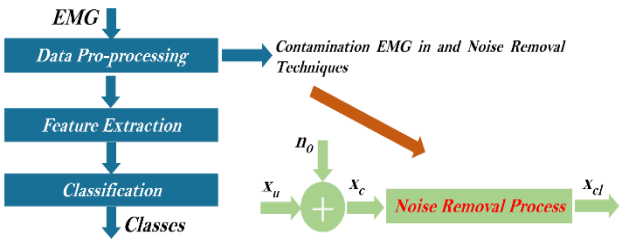


Fig. 1. EMG Signal Processing.

A. Performance Evaluations in Time Domain

Fig.2 mentions the Noise Removal Techniques. Mean absolute error (MAE) is given.

$$MAE=\frac{1}{N}\sum|x_u-x_{cl}| \quad \text{..... (1)}$$

Correlation coefficients (CC) are used

$$CC=\frac{\sum_{k=1}^{N}(x_u(k)-\bar{x}_u)(x_{cl}(k)-\bar{x}_{cl}(k))}{\sqrt{\sum_{k=1}^{N}(x_u(k)-\bar{x}_u(k))^2}\sqrt{\sum_{k=1}^{N}(x_{cl}(k)-\bar{x}_{cl}(k))^2}} \quad \text{..... (2)}$$

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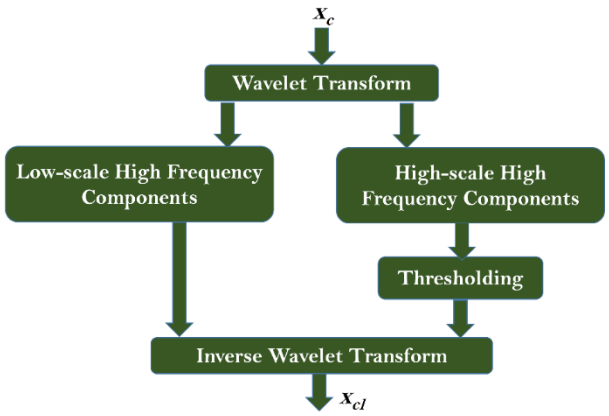


Fig. 2. Noise Removal Techniques

B. Band Pass Filter Design for EMG Signal Analysis

Fig. 3 illustrates the Wavelet Transform in Discrete Stationary (DSWT) Decomposition. Fig.4 highlights the Wavelet Transform in Discrete Stationary (DSWT) Reconstruction. The mathematical model of the bandpass filter is given

$$H(f) = \frac{jf_U^2 f}{(f_L + jf)(f_U + jf)^2} \quad \text{..... (3)}$$

where
f_L is the lower frequency parameter, which is collected from 30-60 Hz
f_U is the upper-frequency parameter, which is collected from 30-100 Hs plus f_L

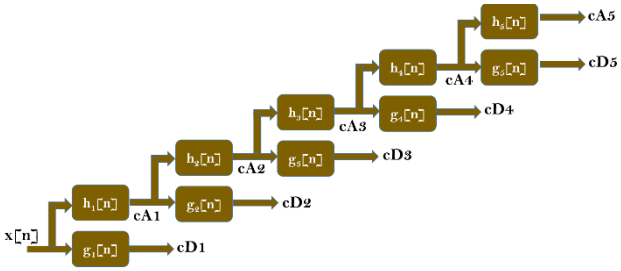


Fig. 3. Discrete Stationary Wavelet Transform (DSWT) Decomposition

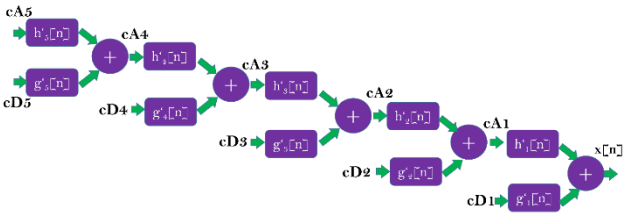


Fig. 4. Discrete Stationary Wavelet Transform (DSWT) Reconstruction

C. EMG Contamination

The EMG contamination could be evaluated according to the signal-to-noise ratio equation as given:

$$SNR = 10\log\left\{\frac{P_x}{P_n}\right\} \quad \text{..... (4)}$$

where
SNR= Signal Noise Ratio
Px=Average Power of EMG Signal
Pn=Average Power of EMG Interference

III. Results And Discussions

A. EMG Signal and its Power Spectrum

The signal processing analysis on normal EMG signal in the time domain and its power spectrum at MAE=0.62578. xu in black color is uncontaminated EMG signal and xc in red color is contaminated EMG signal. Fig.5 shows the EMG Signal and its Power Spectrum.

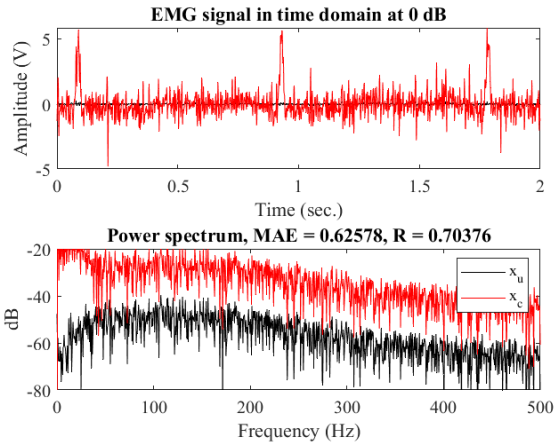


Fig. 5. EMG Signal and its Power Spectrum

B. Normal Signal in Time Domain and Frequency Domain

The normal signal in the time domain and its frequency domain at MAE=0.48613. xu in black color is uncontaminated EMG signal and xc in red color is contaminated EMG signal. Fig. 6 demonstrates the Normal Signal in the Time Domain and Frequency Domain.

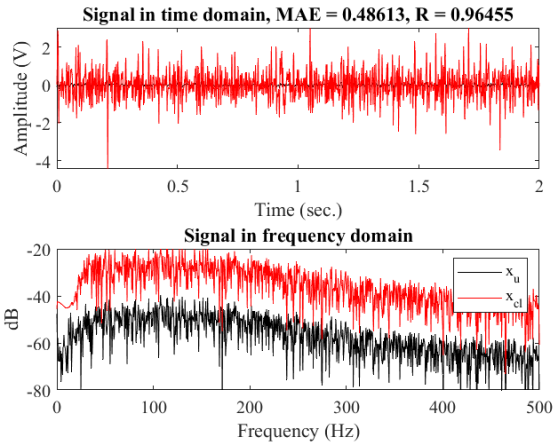


Fig. 6. Normal Signal in Time and Frequency Domain

C. Time Domain EMG Signal and its MAE

The time domain EMG signal at 0dB and its time domain at MAE=0.44983. The signal source from the dataset is analyzed with filtering techniques, especially by Band Pass Filter in approximation and detail collection of EMG signals. Fig. 7 illustrates the Time Domain EMG Signal and its MAE.

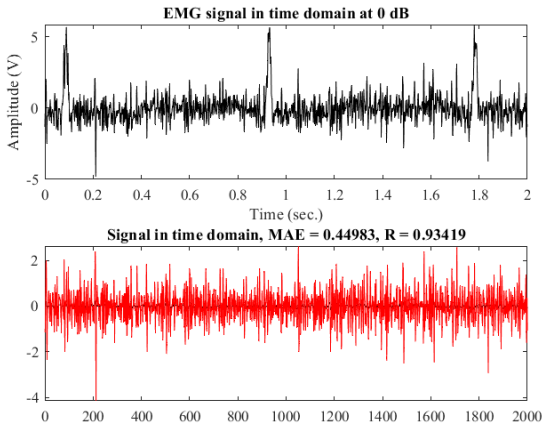


Fig. 7. EMG Signal in Time Domain and MAE

D. Different Types of EMG Signals

The time domain EMG signal at 0dB with different types of EMG signal processing levels with cD1 to cD5. The raw EMG signal and contaminated EMG signal with approximation and detail collection at level 1 to level 3. Fig.8 mentions the Different Types of EMG Signals.

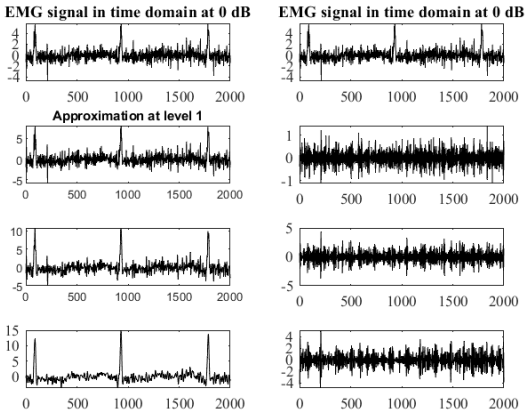


Fig. 8. Different Types of EMG Signals

E. EMG Original and Approximation with Level 1 to 3

The original signal in the frequency domain with different types of EMG signal processing levels from 1 to 3. The EMG signal's power spectrum with raw and contaminated EMG signal with approximation and detail collections at level 1 to level 3. Fig. 9 presents the EMG Original and Approximation with Levels 1 to 3.

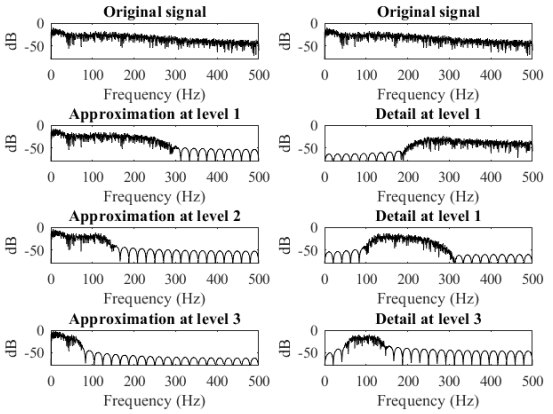


Fig. 9. EMG Original and Approximation with Level 1 to 3

F. Mean Absolute Error (MAE)

The contaminated EMG signal with mean absolute error (MAE) is analyzed from the original raw EMG signal after passing through the different types of signal processing levels. The MAE value for that EMG signal in this study is 3.3602×10^{-6}. Fig. 10 shows the graph of Mean Absolute Error.

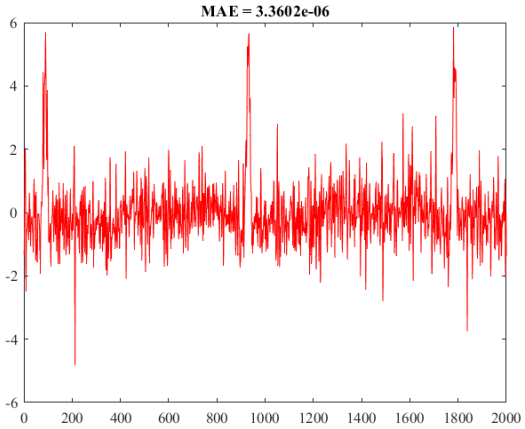


Fig.10. Graph of Mean Absolute Error

G. EMG Approximation with Different Levels in Time and Frequency Domain

EMG signal contaminated with ECG interference at SNR 0 dB (red) and EMG signal contaminated in the time domain (top panel) and frequency domain (bottom panel) (black). The EMG Approximation with Different Levels in Time Domain and Frequency Domain are analyzed based on level 1 to level 3. The analyses are completed with the approximation process for raw EMG signal with filtering techniques. Fig.11 illustrates the EMG Approximation with Different Levels in the Time Domain and Frequency Domain.

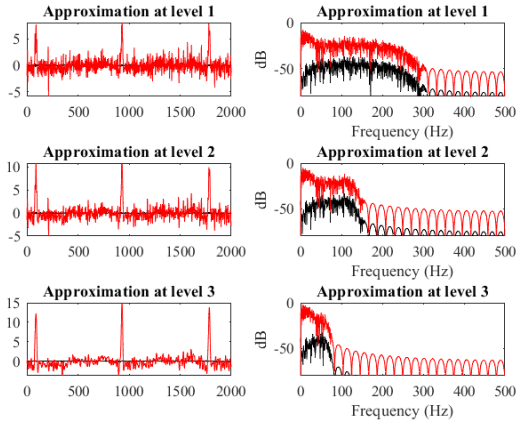


Fig. 11. EMG Approximation with Different Levels in Time and Frequency Domain

H. EMG Detail with Different Levels in Time and Frequency Domain

SNR 0 dB (red) and approximate and detailed statistics were obtained by applying three-level DSWT decomposition of ECG disturbances in the time domain (left column) and frequency domain (left column). The EMG Detail with Different Levels in Time and Frequency Domain are analyzed based on levels 1 to level 3. The analyses are completed with the detail collection for raw EMG signal with filtering techniques. Fig. 12 shows

the EMG Detail with Different Levels in Time and Frequency Domain.

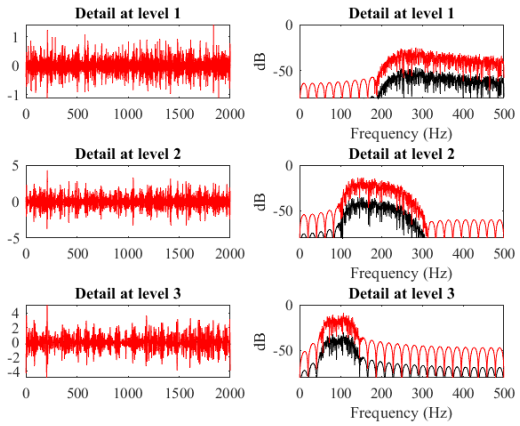


Fig. 12. EMG Detail with Different Levels in Time and Frequency Domain

I. Time Domain EMG Signal with Before Thresholding and After Thresholding Condition

The Time Domain EMG Signal with Before Thresholding and After Thresholding Condition are analyzed based on DSWT and ECG interference. The analyses are completed with the SNR estimation and thresholding estimation in the frequency domain with accurate conditions. Fig. 13 demonstrates the Time Domain EMG Signal with Before Thresholding and After Thresholding Condition.

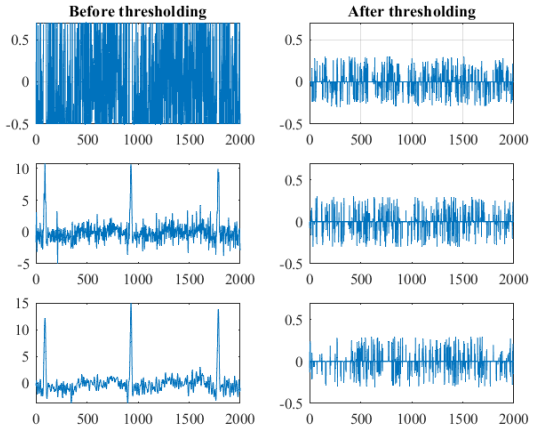
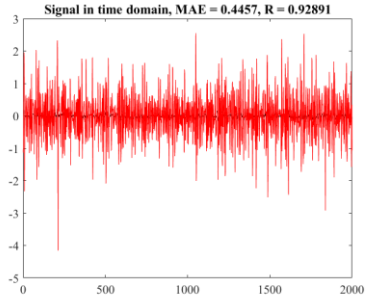


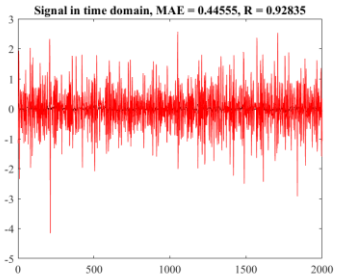
Fig. 13. Time Domain EMG Signal with Before Thresholding and After Thresholding Condition

J. Reconstructed EMG Signal

The time domain Reconstructed the EMG Signal with MAE values of 0.4457 and 0.44555 after completing the signal processing techniques. Fig.14 mentions the Reconstructed EMG Signal.



(a) EMG Signal with MAE values of 0.4457



(b) EMG Signal with MAE values of 0.44555

Fig. 14. Reconstructed EMG Signal

IV. Conclusion

Removal of threshold values with different coefficients of cD1 to cD5 in the nonlinear condition of EMG contamination of ECG disturbance based on DSWT. The SNR estimation and Threshold estimation in ECG disturbance and contaminated EMG signal are analyzed by separate signal waveforms. After completing the signal processing techniques, the EMG signal is reconstructed in the time domain with MAE values of 0.4457 and 0.44555. According to a recent literature survey, there are four types of contaminating noise in the EMG signal; ECG disturbances; power line disruption; and There are four types of motion artifacts and basic noise. A proper method needs to be used to achieve better accuracy and performance. Among them, one can analyze the noise contaminating the EMG signal. Basic concepts of signal processing will be applied to EMG signal processing.

Conflicts Of Interest

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

Author Contributions

This study mainly focuses on contamination in Electromyography (EMG) Signals by using Noise Removal Techniques. Theoretical analyses of mathematical models for EMG Signal Processing play an important role in developing high-performance Biomedical Instrumentation systems for the development of future Smart Health Care Technology. This work can contribute to finding solutions to research problems in advanced high-performance Biomedical Instrumentation design under practical measurement and instrumentation system design.

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Mrs. Nandar Oo received B.E. from Technological University (2009), and her M.E. from Technological University (2012). She joined Technological University (Myitkyina), Myanmar as a tutor at the Department of Electronic Engineering in 2017. She is now a PhD candidate at the Department of Electronic Engineering of Yangon Technological University. (email: manandaroo.ytu@gmail.com).



Dr. Hla Myo Tun is a Leading Pro-Rector for Research and Engineering Higher Education at Yangon Technological University (YTU), Myanmar. He specializes in professional training for Engineering Higher Education leaders, heads of departments, and faculty members. He also directs Research and Development programs and workshops and has worked as a certified Quality Assurance Evaluator of the Myanmar Engineering Council (MEngC) since 2019. (email: hmt.ytu@gmail.com).



Mr. Devasis Pradhan has worked as an Assistant Professor in Grade 1 and Dean of Research and Development at Acharya Institute of Technology, Bengaluru, Karnataka, from 2017 onwards. His current research includes the effectiveness of 5G Green Communications, mmWave antenna design, UWB antennas, and its implementation. With 16+ years of experience in the Academic and Research field, he has published 76 research papers and eight papers submitted to IEEE Access and Reputed Book and 4 Authored Books and 3 Edited Books (CRC, ISTE, Bentham Science) with a reputed publishing house. (email: devasispradhan@acharya.ac.in).



Dr. Lei Lei Yin Win is a Professor at the Department of Electronic Engineering at Yangon Technological University, Myanmar. (email: maleileiyinwin.ytu@gmail.com).



Dr. Mya Mya Aye is an Associate Professor at the Department of Electronic Engineering at Yangon Technological University (YTU), Myanmar. (email: mamyamyaaye.ytu@gmail.com).



Ms. Thandar Oo received B.E. from Technological University (2012), M.E. from Mandalay Technological University (2015), and PhD from Prince of Songkla University (2019). She joined Yangon Technological University, Myanmar as a tutor at the Department of Electronic Engineering in 2021. (email: mathandaroo.ytu@gmail.com).