EMG Signal Processing

Introduction

Electromyography (EMG) measures the electrical activity of skeletal muscles, providing valuable insights into neuromuscular function. This report explores EMG signal processing techniques and their applications in medical diagnostics, rehabilitation, and assistive devices. The goal is to simulate EMG signals, process them to extract meaningful information, and demonstrate their real-world relevance.

Methodology

Synthetic EMG Signal Generation

A synthetic EMG-like signal was generated to replicate the noisy, burst-like characteristics of real EMG signals. This signal combines:

- **Random Gaussian Noise:** Simulates interference from the environment.
- **Burst of Sine Wave (50 Hz):** Represents muscle activation.

Parameters:

- Sampling Frequency: 1000 Hz
- Duration: 1 second

Signal Processing Techniques

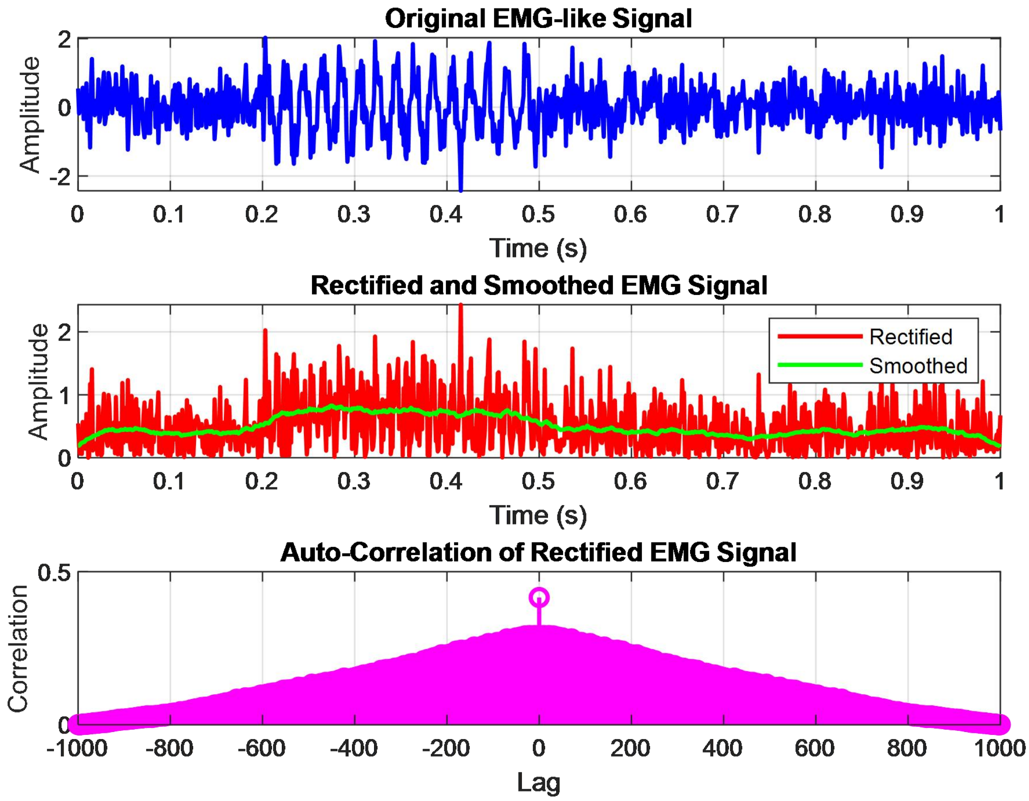
1. **Full-Wave Rectification**
    - Converts the raw signal to absolute values, ensuring all amplitudes are positive.
    - Highlights muscle activation by emphasizing magnitude.
2. **Smoothing with a Moving Average Filter**
    - Reduces high-frequency noise while retaining key features.
    - Applied over 50 samples to reveal trends in muscle activity.
3. **Auto-Correlation Analysis**
    - Evaluates the temporal structure of the rectified signal.
    - Detects periodicity and identifies dominant frequencies.

CODE:

```
% Step 1: Initialize Parameters
Fs = 1000; % Sampling frequency (Hz)
t = 0:1/Fs:1; % Time vector (1 second duration)

% Step 2: Generate Noise and Burst
noise = 0.5 * randn(size(t)); % noise
burst = sin(2 * pi * 50 * t) .* (t > 0.2 & t < 0.5); % Sine wave burst
emg_signal = noise + burst; % Combine noise and burst
```

```matlab
% Step 3: Plot Original EMG-like Signal
figure;
subplot(311); % First plot: Original signal
plot(t, emg_signal, 'b', 'LineWidth', 1.5);
xlabel('Time (s)');
ylabel('Amplitude');
title('Original EMG-like Signal');
grid on;

% Step 4: Full-Wave Rectification
rectified = abs(emg_signal); % Full-wave rectification

% Step 5: Design Moving Average Filter
M = 50; % Number of taps for the filter
filter = ones(1, M) / M; % Moving average filter

% Step 6: Smooth the Rectified Signal
smoothed_emg = conv(rectified, filter, 'same'); %filter

% Step 7: Plot Rectified and Smoothed Signals
subplot(312);
plot(t, rectified, 'r', 'LineWidth', 1.5);
hold on;
plot(t, smoothed_emg, 'g', 'LineWidth', 1.5);
hold off;
xlabel('Time (s)');
ylabel('Amplitude');
title('Rectified and Smoothed EMG Signal');
legend('Rectified', 'Smoothed');
grid on;

% Step 8: Perform Auto-Correlation
[correlation, lag] = xcorr(rectified, 'biased');

% Step 9: Plot Auto-Correlation
subplot(313);
stem(lag, correlation, 'm', 'LineWidth', 1.5);
xlabel('Lag');
ylabel('Correlation');
title('Auto-Correlation of Rectified EMG Signal');
grid on;
```

WAVEFORMS:



Key Observations

- **Amplitude Range:** 50 µV to 5 mV, increasing with muscle exertion.
- **Frequency Range:** 20 Hz to 500 Hz, with energy concentrated between 50 Hz and 150 Hz.
- Fatigue causes a shift toward lower frequencies.

Applications

Medical Diagnosis and Monitoring

- Detects neuromuscular disorders like ALS and muscular dystrophy.
- Analyzes abnormal patterns to identify nerve damage.

Rehabilitation and Physiotherapy

- Tracks recovery progress after injuries.
- Biofeedback systems enable patients to improve motor control.

Prosthetics and Human-Machine Interaction

- Myoelectric prosthetics use EMG signals for intuitive control of artificial limbs.
- Integrated into exoskeletons for physically impaired individuals.

Conclusion

This project demonstrates the importance of EMG signal processing for extracting actionable insights. Techniques like rectification and smoothing enhance interpretability, while auto-correlation provides a deeper understanding of muscle dynamics. Real-world applications underscore the significance of these methods in improving lives through better diagnostics, rehabilitation, and assistive technologies.