

# Understand the fundamentals of EMG signal pre-processing.

```
clc;
clear all;
close all;

% Load the struct from ES1_emg.mat file
load("ES1_emg.mat");

% Extract the data
data = ES1_emg.matrix;
Deltoid_emg = data(:, 1);
Deltoid_AccX = data(:, 2);
Deltoid_AccY = data(:, 3);
Deltoid_AccZ = data(:, 4);
```

## ***Filter the Signal with a BPF***

```
% Define sampling frequency and time vector
fs = 2000;
N = length(Deltoid_emg);
t = (0:(N - 1)) / fs;

% Define the filter parameters
low_cutoff = 30; % Lower cutoff frequency (Hz)
high_cutoff = 450; % Higher cutoff frequency (Hz)
nyquist_freq = fs / 2; % Nyquist frequency

% Design the bandpass FIR filter using the 'fir1' function
filter_order = 100; % Adjust the filter order as needed
filter_coefficients = fir1(filter_order, [low_cutoff/nyquist_freq,
high_cutoff/nyquist_freq], 'band');

% Apply the filter to the EMG signal using 'filtfilt'
filtered_emg = filtfilt(filter_coefficients, 1, Deltoid_emg);
```

## ***Rectify the Signal***

```
% Apply full-wave rectification to the filtered EMG signal
rectified_emg = abs(filtered_emg);
```

## ***Compute the Envelope***

```
% Define the filter parameters for the low-pass filter
lowpass_cutoff = 5; % Frequency cutoff for low-pass filter (Hz)

% Design the low-pass FIR filter using the 'fir1' function
lowpass_filter_order = 100; % Adjust the filter order as needed
```

```

lowpass_filter_coefficients = fir1(lowpass_filter_order, lowpass_cutoff/
nyquist_freq, 'low');

% Apply the low-pass filter to the rectified EMG signal
envelope_emg = filtfilt(lowpass_filter_coefficients, 1, rectified_emg);

```

## Downsampling

```

% Define the downsampling factor
downsampling_factor = 4; % Adjust the factor as needed

% Downsample the envelope signal
downsampled_emg = downsample(envelope_emg, downsampling_factor);

% Create a new time vector for the downsampled signal
t_downsampled = downsample(t, downsampling_factor);

```

## Plots

```

figure;

% Plot 1: Original EMG signal overlaid with the filtered signal
subplot(3,1,1);
plot(t, Deltoid_emg, 'b', 'LineWidth', 1);
hold on;
plot(t, filtered_emg, 'r', 'LineWidth', 1);
title('Raw EMG Signal and Filtered Signal');
xlabel('Time [s]');
ylabel('EMG [mV]');
legend('Raw EMG', 'Filtered EMG');
grid on;

% Plot 2: Rectified EMG signal overlaid with the envelope
subplot(3,1,2);
plot(t, rectified_emg, 'b', 'LineWidth', 1);
hold on;
plot(t, envelope_emg, 'r', 'LineWidth', 1);
title('Rectified EMG Signal and Envelope');
xlabel('Time [s]');
ylabel('EMG [mV]');
legend('Rectified EMG', 'Envelope');
grid on;

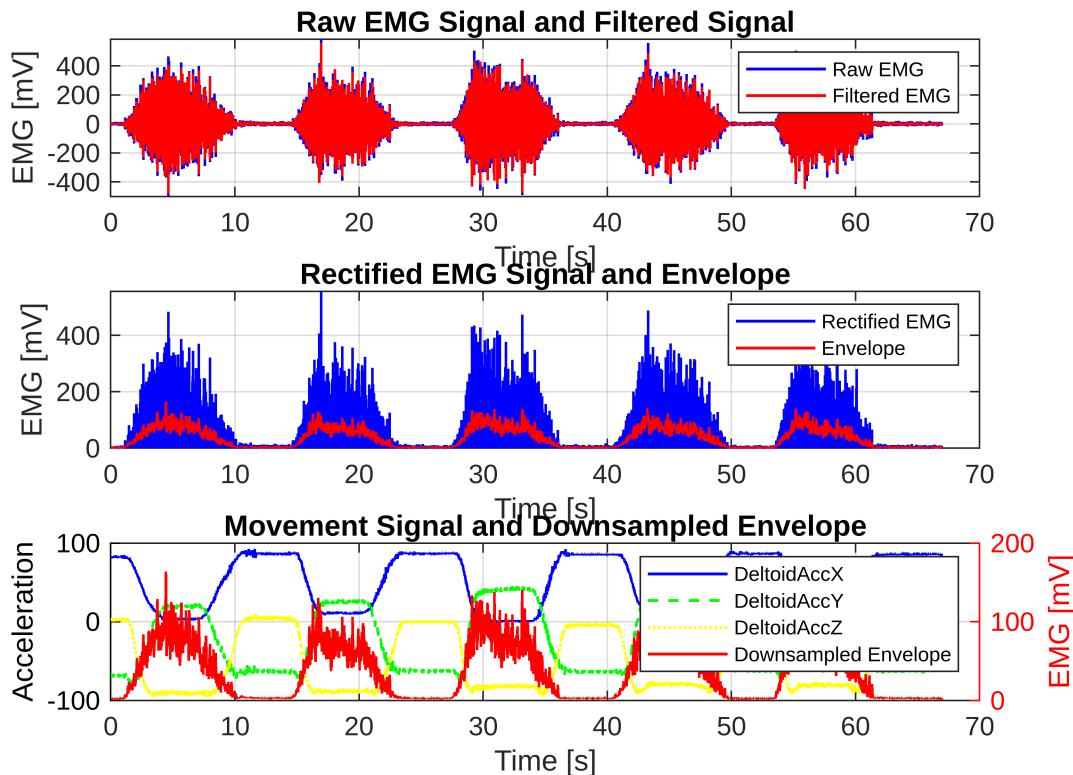
% Plot 3: Movement signal overlaid with the downsampled envelope
subplot(3,1,3);
ax = gca;
yyaxis left
plot(t, 100*Deltoid_AccX, 'b', 'LineWidth', 1);
% Boh, il *100 l'ho tirato fuori dal culo sennò non si vedevano i segnali

```

```

hold on;
plot(t, 100*Deltoid_AccY, 'g', 'LineWidth', 1);
hold on;
plot(t, 100*Deltoid_AccZ, 'y', 'LineWidth', 1);
hold on;
yyaxis right
ax.YColor = 'r';
plot(t_downsampled, downsampled_emg, 'r', 'LineWidth', 1);
title('Movement Signal and Downsampled Envelope');
xlabel('Time [s]');
ylabel('EMG [mV]', 'Color', 'r');
yyaxis left
ylabel('Acceleration', 'Color', 'k');
legend('DeltoidAccX', 'DeltoidAccY', 'DeltoidAccZ', 'Downsampled Envelope');
ax.YColor = 'k';
grid on;

```



**Answer to Question A:** Down-sampling is performed after envelope computation to reduce data size and processing requirements. Enveloping smoothes out the signal and reduces the impact of high-frequency noise, making it suitable for further down-sampling without significant loss of information.

**Answer to Question B:** In the graph 'Movement Signal and Downsampled Envelope' we have amplified the acceleration values by a factor of 100, because otherwise we weren't able to compare the two different range values.

Looking at this graph, in particular 'Downsampled Envelope' (red line) and 'DeltoidAccY' (green line) signals, we notice that there is a slight delay between the activation of the EMG signal and the movement: this delay consists in a preparation phase of the muscle to the activation of movement, and its absence is the cause of diseases and dysfunctions.