UNIVERSITA DEGLI STUDI DI GENOVA

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DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY,
BIOENGINEERING, ROBOTICS AND SYSTEM ENGINEERING

Biomedical Robotics

First Assignment

EMG Assignment

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November 9, 2023

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1 Exercise 1: MATLAB

EMG signals, derived from the electrical activity of muscles, serve as a fundamental component in the development of EMG-based control systems. These systems find applications in assisting individuals with limited mobility by allowing them to control devices, such as robotic arms, using muscle activation signals. The success of such systems heavily relies on the preprocessing of EMG signals, as it significantly impacts the accuracy and reliability of control.

1.1Methodology:

The preprocessing of EMG signals involves a series of essential steps:

1. Band-Pass Filtering:

One of the initial steps in preprocessing EMG signals is band-pass filtering. The purpose of this filtering is to eliminate unwanted frequencies while retaining the relevant components of the signal. In our case, the band-pass filter with a range of 30-450 Hz is employed, as indicated in the code. This filtering effectively removes noise and ensures that the signal primarily contains muscle-related information.

2. Rectification:

After band-pass filtering, the next step is rectification. The rectification process transforms the filtered EMG signal into a full-wave signal, removing negative values. This is accomplished by taking the absolute value of the filtered signal, which simplifies further analysis and facilitates the extraction of muscle activation characteristics.

3. Envelope Computation:

Following rectification, the envelope of the signal is computed. This involves using a low-pass filter with a cutoff frequency of 5 Hz (as in the provided code). The envelope represents the smoothed amplitude variations of the signal, providing a more interpretable representation of muscle activity. The low-pass filtering attenuates high-frequency noise and leaves behind the essential features related to muscle activation.

4. Downsampling:

The last step in preprocessing involves downsampling the envelope of the EMG signal. Down-sampling reduces the number of data points, which is beneficial for efficiency and storage. In this code, a downsampling factor of 4 is applied, effectively reducing the data size.

1.2 Question A: Down-Sampling and Envelope Computation:

The choice of performing down-sampling after the envelope computation is significant. Down-sampling is usually carried out after envelope computation because the envelope typically contains lower-frequency components compared to the raw signal. Down-sampling retains important information while reducing the data size. This is essential for efficient processing and analysis without losing the primary characteristics of the envelope.

1.3 Question B: Temporal Relationship Between Muscle Activation and Movement:

To understand the temporal relationship between muscle activation and movement, additional analysis is required. Synchronization of the EMG signal and motion data is necessary. The onset of muscle activation can be determined by setting a suitable threshold for the envelope. Simultaneously, the onset of movement in the motion data can be detected. By comparing the timing of these onsets, we can assess the temporal relationship between muscle activation and movement. This analysis is a crucial step in the development of EMG-based control systems and can help in determining when muscle activation commences concerning movement initiation.

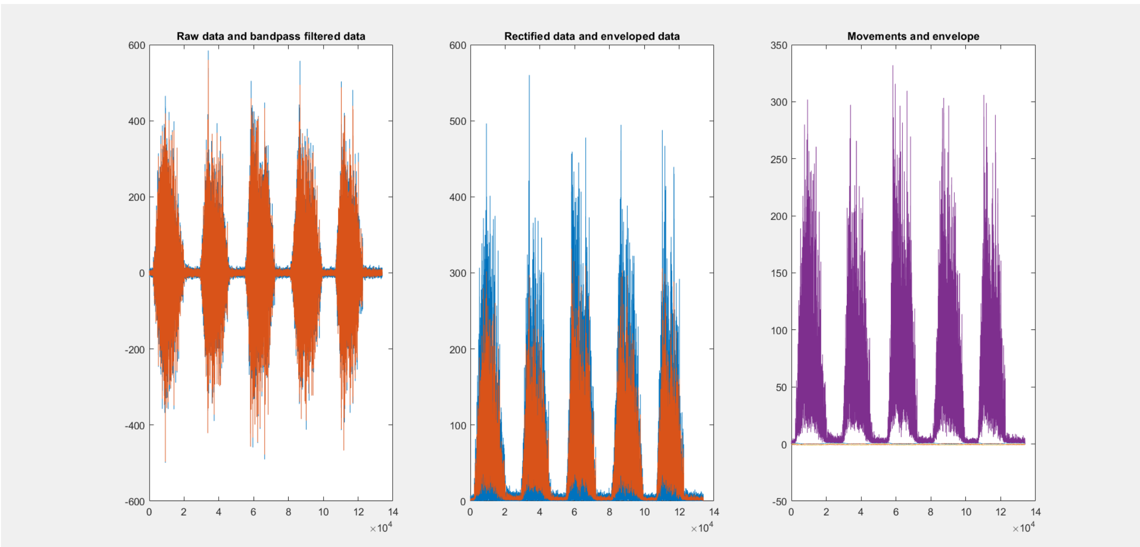

Figure 1: Results of the first exercise

2 Exercise 2: MATLAB Simulink

2.1 Case 1: Reaching Horizontal and vertical target points

To control the cursor movement to reach the horizontal and vertical target points, first EMG data is acquired from 'ES2_emg.mat' file, which contains EMG data that needs to be loaded in MATLAB. The data is four muscle channels and a sampling frequency of 1000 Hz. In Simulink, the first block was used to import this data that needs to be processed later in a subsystem block in which filtering techniques are applied (bandpass filter) to remove noise and focus on the frequency band of interest of muscle activity, then the signals are rectified and compared to specific thresholds to move the cursor. A target is reached when the muscle contraction surpasses a chosen threshold. The following figure demonstrates test 1 in Simulink

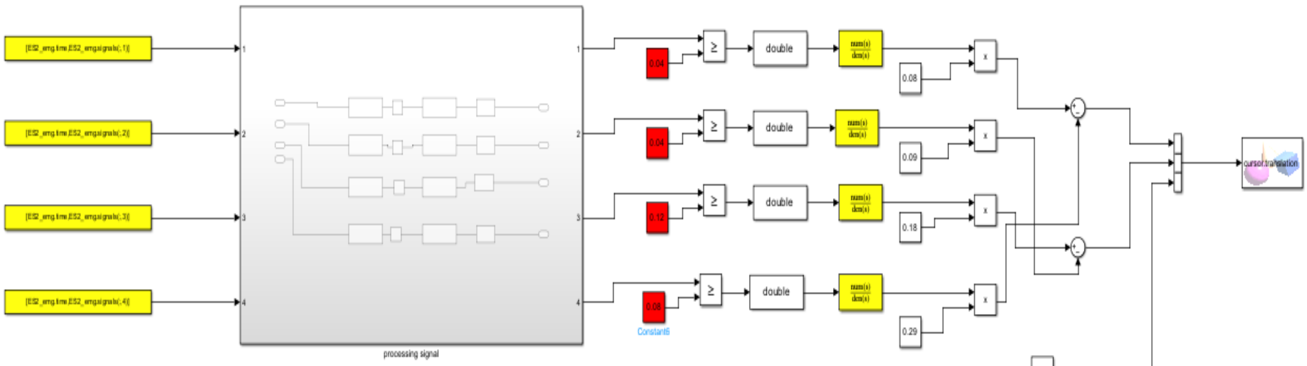

Figure 2: Control of cursor case 1

The .wrl file with the VRsource input block is used to display 8 target points in addition to a cursor. Thus, after running the Simulink test 1, one can achieve the desired behavior illustrated in the following figure as an example of the movement of the cursor to the yellow target.

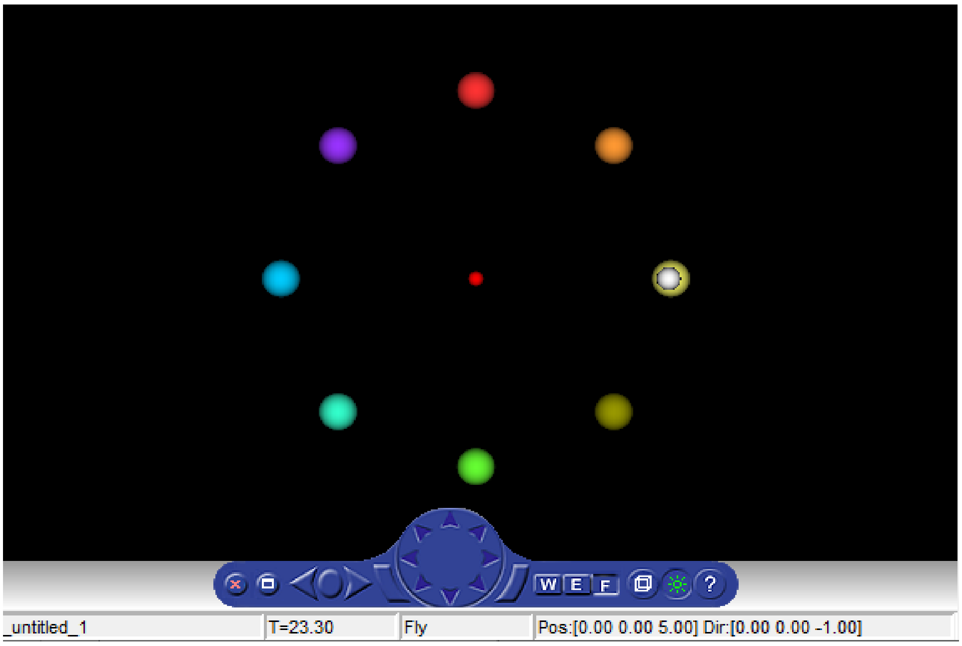

Figure 3: Result simulation on VRsource

2.2 Case 2: Reaching diagonal target points

Similarly in case 1 where the cursor's objective was to reach the 4 vertical and horizontal target points, the EMG muscle signals were mapped to diagonal movements to be able to reach the diagonal target points. This was done by combining signals from the two muscles. The main system in the simulink file, as shown in figure below, contain the following (listing the important blocks):

- Workspace block to import the EMG data into the simulink model
- Relational Operator Block with constant threshold: To trigger cursor movements, the comparison between the processed EMG signals and a designated threshold value is essential. This is where the relational operator block comes into play, aiding in the determination of when the amplitude of the EMG signal surpasses a certain point (A target is reached when the muscle contraction surpasses a chosen threshold)
- Conversion of data types to double: this block is just to ensure that the output type is double
- TransferFcn Block: This block is used for smoothing and noise reduction
- Product Block: It is responsible for amplifying the signals so we multiply the signal with a constant. A gain block can also be used for this purpose. Then all the signals are summed up to derive the overall signal that will result in the movement of the cursor.
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Additionally, the simulink file contains a subsystem which represents the overall filter block, where the main components are listed below:

- Bandpass Filter Block: this is to remove noise and filters the EMG signals to keep only the frequency components of interest, in this case the muscle activity. The square block was added to rectify the signal.
- Lowpass Filter Block: to ensure signal continuity and reduce noise and jitter. Then the signals were downsampled to 100 to make the application faster and the computation and simulation less heavy.

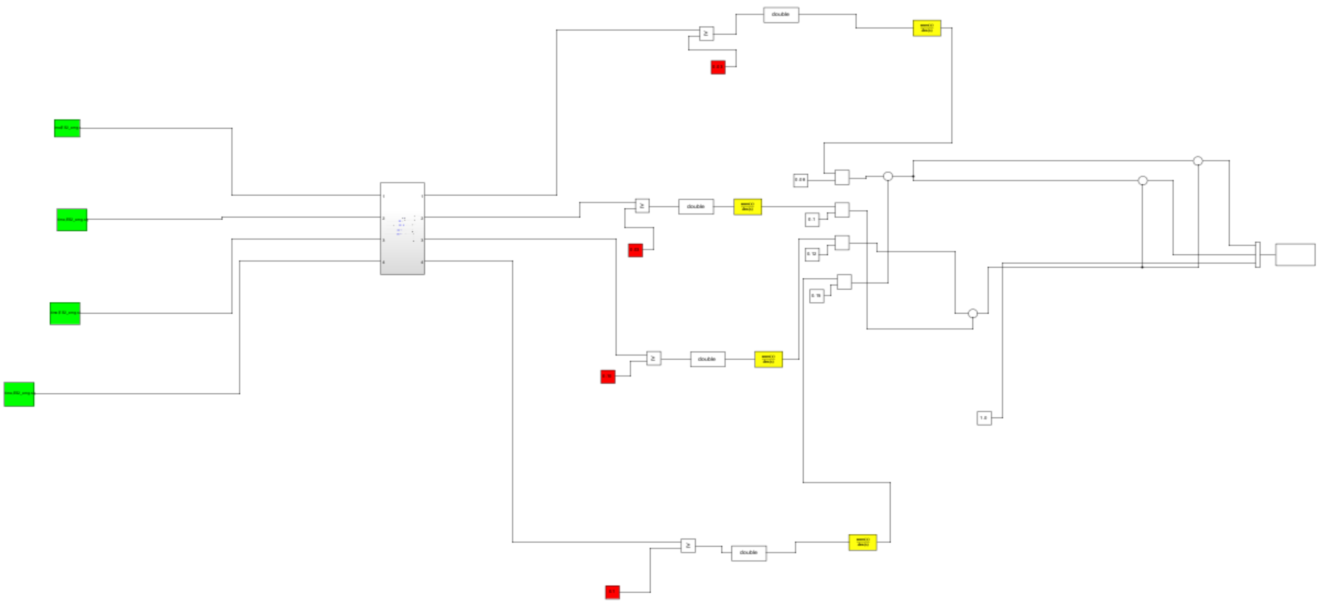

Figure 4: Control of cursor case 2

The results are the cursor moves to the diagonal target points starting with the violet point and finishing with the yellow target point as demonstrated in the figure below.

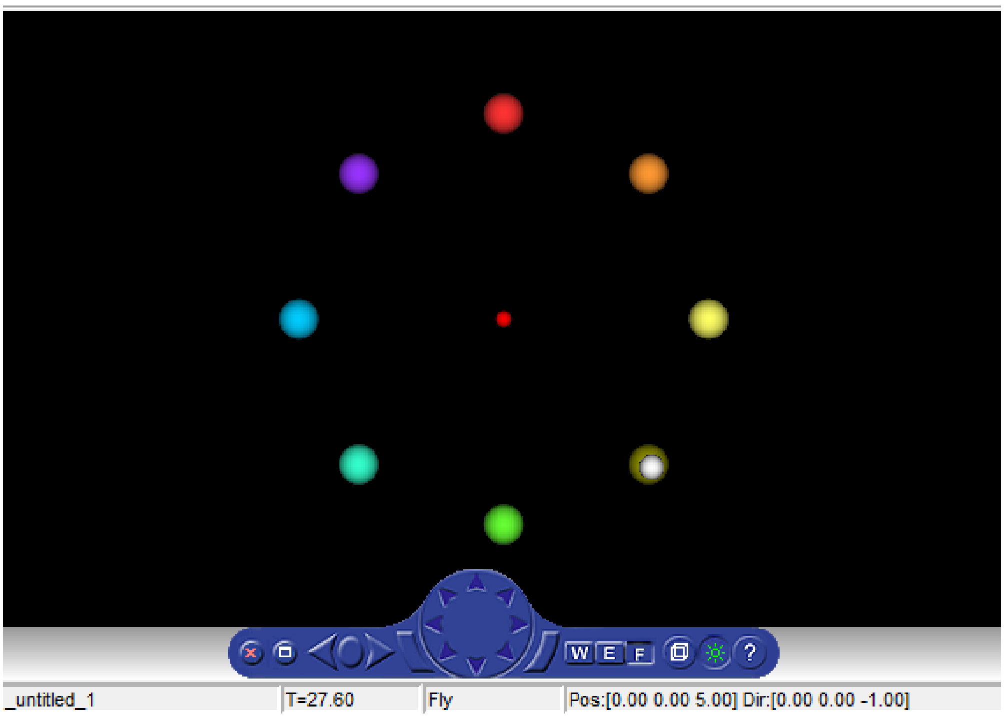

Figure 5: Result simulation on VRsource

2.3 Case 3: Reaching the 8 target points

In order to reach the 8 target points this configuration was set in Simulink, refer to figure below:

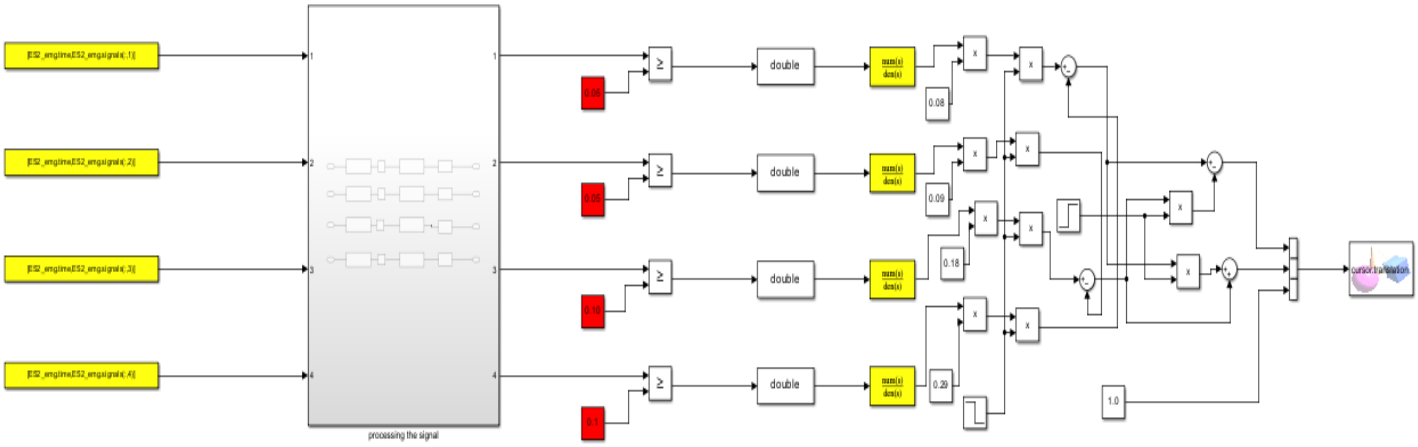

Figure 6: Control of cursor case 3

The step block was added to create a change in a signal at a specific time allowing you to model sudden changes and transitions in the system. It typically starts at zero, remains constant, and then jumps to a specified value at the specified time.

2.4 Further Methods:

Another method to map the EMG activity to control the cursor to reach the 8 target points is to linearly assign the muscles signals to specific X and Y coordinates. Meaning that the muscle signals will be directly proportional to the path and the waypoints of the cursor. Also in this method, it is necessary to preprocess the EMG data real-time and remove the noise. It can be more straightforward however, it is more time consuming to implement, the more waypoints/precise we want the path for the cursor to take the more data we will need. Another possible way to control the movements of the cursor is to control it based on velocity instead of coordinates. In this case, we will map the EMG signal to control the cursor vertical and horizontal velocity. The movement of the cursor but also be limited by a threshold. Similarly, in case 1, 2 and 3 the thresholds will indicate that the cursor has reached the target point.