UNIVERSITA DEGLI STUDI DI GENOVA

BIOMEDICAL FOR ROBOTICS

Assignement 1

DIBRIS

DEPARTMENT OF COMPUTER SCIENCE AND

TECHNOLOGY, BIOENGINEERING, ROBOTICS

AND SYSTEM ENGINEERING

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Exercise 1 - Matlab

Goal: Understand the fundamentals of EMG signal pre-processing.

Link to the matlab script: Ex_1

Answering questions:

Question A: Why is the down-sampling performed after the envelope computation?

Down-sampling is carried out following the calculation of the envelope, which is designed to extract low-frequency components or gradual signal variations while eliminating high-frequency components or noise that might be present. This process reduces the volume of data that needs to be processed. Down-sampling lowers the signal's sampling frequency, simplifying data complexity and streamlining subsequent analysis or processing, all while preserving essential information. The decision to perform down-sampling after calculating the envelope is due to the fact that the signal's envelope contains all the necessary information. When down-sampling is applied to a signal that has already undergone pre-processing and filtering, there is no loss of consistent signal information. In fact, if down-sampling had been applied directly to the original signal, a new signal would have been obtained, comprising a mixture of noise and signal samples, resulting in the complete loss of the original signal information. Consequently, the analysis would pertain to something other than a muscular signal.

Question B: Based on the motion signal, when does the muscle activation commence in relation to the movement

Clearly, in the latest graph, through precise alignment, we successfully overlaid the motion signal with the envelope. A closer inspection reveals that the envelope signal activates approximately 150 ms ahead. This early envelope activation can be attributed to muscle preparation: before a muscle can generate sufficient force to initiate a visible movement, it must be primed and activated. Muscle electrical activity initiates at the cellular level when the nervous system sends signals to the muscle motor units, stimulating them to contract. This process entails some time, resulting in the emergence of the EMG signal before observable movement. The envelope's early activation falls within a range of 100ms to 200 ms.

This observation was made possible by the high sensitivity of the electrodes used to record the EMG signal. These electrodes exhibit remarkable sensitivity to muscle electrical activity, capable of detecting even subtle variations in muscle activity before they manifest as visible movement."

Exercise 2 - Simulink

Goal: Learning the basics of EMG-based control. You will learn to manipulate a cursor on the screen using EMG signals.

Link to the matlab script:

1. Ex_2.1 (to load the data)
2. Ex_2.2 (to reach the cardinal points)
3. Ex_2.3 (to reach the diagonally points)
4. Ex_2.4 (to reach all the points)

Answering questions:

Question A: Identify any potential drawbacks associated with this alternative mapping method.

Both types of control have advantages and disadvantages depending on the applications and how they are implemented.

Position control offers a high degree of precision in cursor positioning. This approach allows users to move the cursor precisely and intuitively in the desired direction, which can be particularly useful for tasks that require precision. However, maintaining a fixed position over time can be tiring for users, as it requires constant muscle activity and can lead to muscle fatigue. Additionally, position control may not be optimal for tasks that require fast or continuous cursor movements.

On the other hand, with velocity control, users can control the cursor's movement speed through EMG signals, allowing them to move the cursor quickly or slowly. This is advantageous for tasks that require a rapid response or dynamic cursor movements. However, velocity control may result in a certain lack of precision, as it is more challenging for users to position the cursor accurately at a desired point. Furthermore, managing the acceleration and deceleration of the cursor can be complex, leading to abrupt or unpredictable movements if not well-controlled.

In both cases, it is important to consider how users adapt to each type of control and how they feel when using the system. User feedback and practical experience are essential for determining which control approach is most suitable for a given application. Additionally, you can combine the advantages of both methods by implementing a system that allows users to switch between position and velocity control based on the specific task's requirements.

Question B: Can you think of a different way to map the EMG activity to control of the cursor ?

Pattern Recognition-Based Control Approach:

The control of a cursor using EMG signals can be achieved through pattern recognition techniques. This method involves the utilization of pattern classification techniques to identify and extract concealed signal information. By employing pattern classification, distinct patterns can be derived from EMG signals, facilitating the recognition of intended movements. Once a pattern is detected, the cursor is activated, and the desired movement is executed with a high level of accuracy.

An EMG pattern recognition-based control approach generally comprises three key stages: EMG measurements, feature extraction, and classification. Initially, EMG measurements are conducted to capture more reliable myoelectric signals. Subsequently, features are extracted from the data to preserve the most significant discriminatory information from the EMG signals. Finally, a classification algorithm is employed to predict the intended movements.

EMG signals are represented as time sequences. Directly passing them to the classifier is impractical, primarily due to the high dimensionality of the recorded data. Consequently, the sequence must be transformed into a lower-dimensional vector, referred to as a feature vector. In the final stage, linear or nonlinear algorithms (classifiers) assign the extracted features to the class they most likely belong to. In EMG pattern recognition systems, Principal Component Analysis (PCA) is a fundamental technique used in the preprocessing phase for dimensionality reduction. PCA simplifies high-dimensional data while preserving trends and patterns.

During a training phase, users perform actions, and the system records and labels the corresponding EMG patterns. Real-time recognition is then employed to classify user-generated EMG signals and manipulate the mouse pointer accordingly. Feedback and adaptation are pivotal in helping users become familiar with the system and ensuring its accuracy. The recognition algorithm should be responsive, robust, and capable of handling multiclass classification for various mouse functions. Users may require an adjustment period, and thresholds or decision rules can be implemented to prevent unintended actions.