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Biomedical Robotics

Report Assignment

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1 EMG

Exercise 1 - Matlab

Q1. Why is the downsampling performed after the envelope computation?

Downsampling is done after the envelope because, after the low-pass filter at 6 Hz, the highest frequency component of the signal is now 6 Hz. According to Nyquist's theorem, the new sampling frequency should be at least 12 Hz (6 Hz * 2) to prevent aliasing. In this case, we downsample with a factor of 100, reducing the sampling frequency from 2000 Hz (original sampling frequency) to 20 Hz, which still satisfies the Nyquist criterion.

Downsampling is performed after envelope computation to prevent aliasing and preserve meaningful signal information. Since the original EMG signal contains high frequency components, directly downsampling it would introduce aliasing, leading to signal distortion. By first computing the envelope, high frequency content is removed, ensuring that the signal is properly band-limited before reducing the sampling rate. This approach not only maintains signal integrity but also allows for more efficient data storage and computation while retaining meaningful information about the signal.

Q2. Based on the motion signal, when does the muscle activation commence in relation to the movement?

Looking at the graph of the downsampled envelope and the motion signal (particularly the acceleration in the y-axis), it is observable that there is a slight delay in the motion with respect to the muscle activation. In other words, the muscle activation happens slightly earlier than the motion. This delay can be interpreted as a preparation phase of the muscle before the actual movement.

Exercise 2 - Simulink

Q1. How can you reach the main 4 cardinal directions displayed on the screen?

The proposed implementation consisted on, first, pre-processing all 4 signals by applying the bandpass filter (from 30 Hz to 450 Hz), rectification, envelope (low-pass filter at 6 Hz) and downsampling (at a factor of 50), in that order. With an original sampling frequency of 1000 Hz and a downsampling by a factor of 50, the resulting sampling frequency is 20 Hz. Therefore, the final processed signal respects Nyquist's rule since (6 Hz x 2) $<$ 20 Hz.

Afterwards, we plotted all processed muscle signals with respect to time in order to identify a proper threshold for each muscle and also to verify if there were any superposition (more than one muscle active simultaneously). Then, we considered two ways of mapping the signal to the cursor position:

1. Sum-based: For each signal, we used a switch block that outputs a cardinal position vector if the signal surpasses the defined threshold. The outputs of all switch blocks are joined in a sum block. The output of the sum is passed to the VR block. With this particular dataset, this solution works because there are no superimposed signals over the defined thresholds. However, if the dataset had multiple muscles active at the same time, then the final position vector could be not one of the 4 cardinal points (it could be the center or one of the corners of a 0.1 x 0.1 square).
2. Priority-based: For each signal, we used a switch block that outputs "1" if the signal surpasses the defined threshold. The outputs of all switch blocks are inputted into a function that maps the active muscle to the coordinate of a cardinal point through an if-else condition. With this approach, the cursor will always go to one of the cardinal points. However, if there is more than muscle active, the cursor will follow the point associated to the muscle with higher priority in the if-else condition.

Q2. How can you reach the other 4 diagonal directions displayed on the screen?

The implementation was exactly the same as in the previous exercise, but the position vectors associated to each muscle were changed. Instead of using the 4 cardinal coordinates, we used the diagonal ones.

Q3. Can you think about a different way to map the muscles and be able to reach all 8 targets with the activation of these muscles? Explore an alternative mapping approach between muscles and cursor movement that enables reaching all 8 targets. Identify any potential drawbacks associated with this alternative mapping method.

In order to reach all 8 targets we decided to put a lower activation threshold, so that more than one muscle would be active at the same time. As in the previous case, we sum the coordinates associated with the muscles that are active. At this point, we added a new function to handle the cases where multiple signals are high simultaneously and cause the summed coordinates to correspond to one of the corners of a 0.1 x 0.1 square, where there are no targets. In this function, we check if the norm of the coordinates is less than the radius of the circle where the targets are placed. If this condition is not satisfied (coordinates belong to one of the square corners), we have to do some additional checks to understand in which quadrant the coordinates are and forcedly map them to be equal to the target that is in the diagonal of the same quadrant.

A possible drawback is that if the activated signals correspond to muscles that are mapped with opposite cardinal positions (i.e. up and down, right and left, or all 4 directions are active at the same time), then the summation of their position vectors is equal to zero and the cursor does not move.

Q4. Can you think of a different way to map the EMG activity to control the cursor?

Instead of using a switch that takes as input the signal and, if higher than a threshold, outputs the desired position vector, we can directly normalize the signals in the range [0, 0.1] (which is the radius of the circle where the markers are positioned) in order to remove the switch blocks.

Additionally, with 4 muscle signals there are 16 possibilities for mapping the activation of a single muscle or a combination between them. Our implementation considers only 8 out of the 16 combinations, since the simulation covers only 8 markers. Therefore, a different way of mapping the signals to control the cursor could be considering a different set of 8 muscle activation combinations.

Finally, another way to map signals to cursor position is to use a proportional mapping method. This method would scale the movement of the cursor based on the amplitude of the muscle signal, rather than using a threshold-based on/off control as we did in previous cases. Therefore, the cursor could move in the direction corresponding to the muscle(s) activated with a displacement proportional to the muscle activation level, making the cursor reach the goal when the amplitude is high enough.

2 Phantom Omni

Q1. Define how to compute a field that attracts the end effector towards the target. How to have a field that rejects from the target instead?

We defined the force field as the summation of an elastic force field plus a viscous one. The elastic force field is defined as a force that attracts the end effector to the target. It was defined as the product between the error in position of the end effector, a negative gain and a 3x3 identity matrix in order to apply the force on all components while keeping the force vector homogeneous.

For the viscous force we used the same procedure, but we multiplied by the velocity of the end effector instead of its position error.