Assignment A – #10

Materials

The file *"ENUME 2025 - Assignment A - Estimation of lower limb joint angles.pdf"* contains formulae for computing the angles in the hip, knee and ankle joints, based on measurement data representing the three-dimensional coordinates of certain points in the lower limbs.

The file *"typical_gait.mat"* contains exemplary measurement data representative of typical human gait, acquired by means of a Vicon motion-capture system. The coordinates of physical and virtual markers, stored in that file, are given in millimeters.

The file *"lpfilt.m"* contains a MATLAB function implementing a certain lowpass digital filter. It can be used according to the following scheme:

$$xf = \textbf{lpfilt}(x, fc)$$

where x is a vector of data to be filtered, fc is the filter's cutoff frequency (in Hz) and xf is the vector of results of filtering.

Task

The above-mentioned lowpass filter can be used for smoothing a sequence of marker coordinates if they are corrupted with measurement errors. The smaller the filter's cutoff frequency, the more the data are smoothed. On the other hand, when the filter's cutoff frequency is very small, the smoothing causes the loss of some information.

A certain motion-capture system provides data similar to the Vicon system, but with worse accuracy: each coordinate of each virtual marker, obtained using that system, is corrupted with a normally-distributed, zero-mean additive error characterised by a standard deviation 15 mm.

Determine – by performing an appropriate simulation in MATLAB – the cutoff frequency which minimises the mean absolute error of the estimates of the left ankle dorsiflexion angle when the lowpass filter is used to smooth marker coordinates obtained using the above-mentioned system. Assume that the data stored in the file *"typical_gait.mat"* are free from errors.

In particular:
- Compute the time course of the left ankle dorsiflexion angle based on the data from the file *"typical_gait.mat"*.
- Generate a set of data emulating the lower-accuracy system: add normally distributed, zero-mean pseudorandom numbers (randn), characterised by the above-mentioned value of standard deviation, to the marker coordinates from the file *"typical_gait.mat"*.
- Smooth those data using the lpfilt function with a selected value of fc.
- Compute the time course of the left ankle dorsiflexion angle once again, this time based on the smoothed noisy data.
- Compute the mean absolute error of the estimates of the left ankle dorsiflexion angle based on the smoothed noisy data by comparing them with the estimates based on the original data.
- Repeat the experiment for different values of fc.

Hint: The optimum cutoff frequency is in the range 0.1 Hz to 20 Hz.