Aim 2 - Calculate motorneuron activation profiles for complete hindlimb actuation

Calculation of joint torques

The simplest method of developing motorneuron signals is to first calculate joint torque about each joint and then decompose the total torque profile into individual muscle forces. This decomposition process has an infinite solution set, as individual muscle contributions can be combined in infinite permutations to generate the torque profile. First, an accurate total torque profile was established based on data from project collaborators. Next, the biomechanics of the system were considered to determine the impact of passive and active torque on the system. Finally, the complete torque profile was decomposed into individual muscle forces through a linear optimization technique. \par

The overall torque profile was calculated for both the stance and swing phase of walking. Stance phase mean joint torque was calculated for rat hindlimb joints during graded walking\cite{andrada\_biomechanics\_2013}. A Simulink model of the hind limb was was developed to determine joint torque during swing phase. \par

To determine torque generating muscle contributions, the passive torque due to body weight must be removed from the overall signal. Using ground reaction forces, it is possible to treat the leg like a multi-segmented arm with a force at the end effector. Joint torques can be calculated by constructing a spatial manipulator Jacobian\cite{murray\_mathematical\_1994}, which combines the joint axes and positions. The composition of the spatial manipulator Jacobian is a 6$\times$n matrix of the form:

EQUATION.

where $\omega$ represents the joint axis and $q\_{n}$ represents a joint's global coordinates.

Load torques are calculated using ground reaction force data\cite{muir\_ground\_1999} from the literature. With the spatial manipulator Jacobian and the ground reaction forces, the sagittal plane load torque in all three joints can be calculated using,

EQUATION.

Active joint torque is the summation of individual muscle torques about each joint. With a method for calculating muscle moment arms in place, the only thing left is to calculate the muscle forces to generate the total torque profile. However, this is an infinite solution space making the outright distribution of muscle forces difficult. To address this problem a linear optimization has been applied.

Linear optimization is appropriate for this problem since it involves the summation of torques. The only difficulty remaining is determining the ideal cost function. The linear optimization process follows the form:

Distribution of muscle forces - optimization

The Canvas System