Using Optimization to Determine Tremor Propagation
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**Introduction:** Essential Tremor (ET) is one of the most common movement disorders, with millions affected in the US. Currently there are two main treatment options: medication and deep brain stimulation (DBS). Available medications are only 50% effective, and in only 50% of patients, and many patients consider DBS too invasive. Surprisingly, there has been little work in developing devices to suppress tremor in the upper limb, where it manifests most commonly. One obstacle to developing effective tremor-suppressing devices is that we do not currently know where in the upper limb the tremor originates (mechanically) and how it propagates. The purpose of our research is to determine the origin and propagation of tremor throughout the upper limb.

**Methods:** Our lab has developed a neuromusculoskeletal model of upper limb movement [1]. This model, which takes muscle activity as input and outputs joint displacement, includes 15 muscles and the seven major degrees of freedom (DOF) from the shoulder to the wrist. With prior measurements of tremorogenic muscle activity and tremorous joint displacement in patients with ET, it is theoretically possible to use this model to determine the origin and propagation of tremor on a patient-specific basis. However, the model parameters are not known for individual subjects. These model parameters include the time constants of the excitation-contraction dynamics for all 15 muscles, the moment arms between the 15 muscles and the 7 DOF, and the coupled inertia, damping, and stiffness for all 7 DOF. The short-term goal of this work is to use optimization to estimate these model parameters for each subject. More specifically, we use known inputs and outputs with a convex optimization model to estimate the optimal model parameters needed to complete the movement. We implemented the optimization in Matlab, minimizing the magnitude of the error between known and simulated inputs/outputs.

**Preliminary Results & Discussion:** So far, our optimization has focused on the portion of the model between joint torques (input) and joint displacements (output) in an effort to estimate the impedance matrices (inertia, damping, and stiffness). Each of the three optimal matrices returned by the optimizer were well within the normal human range and matched closely the previously measured values found in the literature. Figure 1 shows a comparison of input torques to the torque value found with the optimized $I$, $D$, and $K$ matrices, demonstrating that the optimization provided good impedance matrices for the model.

**Conclusion:** Using least squares optimization to match impedance parameters works well and provided consistent results for varying input torques. The success of this optimization strategy warrants further research to expand the model to include muscle excitation-contraction dynamics and the transformation from muscle force to joint torque. Using this expanded model, we can use experimentally measured inputs (EMG) and outputs (tremor) to determine patient-specific values for all model parameters. Once the model parameters are estimated, we can drive the model in a forward simulation to identify how tremor propagates from activity in the 15 muscles to tremor in the 7 DOF.

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**References**