Tutorial 4 – Neural Control Personalization

The Neural Control Model Personalization tool finds muscle synergies that are as consistent as possible with ID joint moments and, when available, MTP-estimated muscle activations. The NCP tool fits muscle synergies at the level of muscle activations (i.e., after electromechanical delay and activation dynamics) for regions of the body where either all muscle activations are available from the MTP tool (e.g., the right lower extremity) or no muscle activations are available.

The inputs to the NCP tool are a post-JMP OpenSim model as well as data for IK motions, ID loads, muscle–tendon lengths and velocities, muscle moment arms, and, optionally, MTP-calculated muscle activations from one or more motion trials of interest.

Before running NCP:

1. Open the OpenSim model **UF_Subject_3_reduced_muscles.osim** in the OpenSim GUI.
2. Under the *Forces* tab on the model, explore the muscles available.
3. Take note of the extra groups added.
    a. These are added for organization so that MTP/NCP knows which model muscles to group together in the optimization.
    b. The four important groups are:
        i. Activation Muscle Groups – Muscles that we would expect to have similar activation profiles (ie lateral hamstrings; BFSH and BFLH will have similar activations to each other). *These groups are used in MTP and NCP. *
        ii. Normalized Fiber Length Muscle Groups – Muscles that we would expect to have similar normalized fiber lengths. *These groups are used in MTP and NCP. *
        iii. Collected EMG Muscle Groups – Muscle groups that we **do have** experimental EMG data for. These must have the same name as the respective EMG channel name your EMG data file

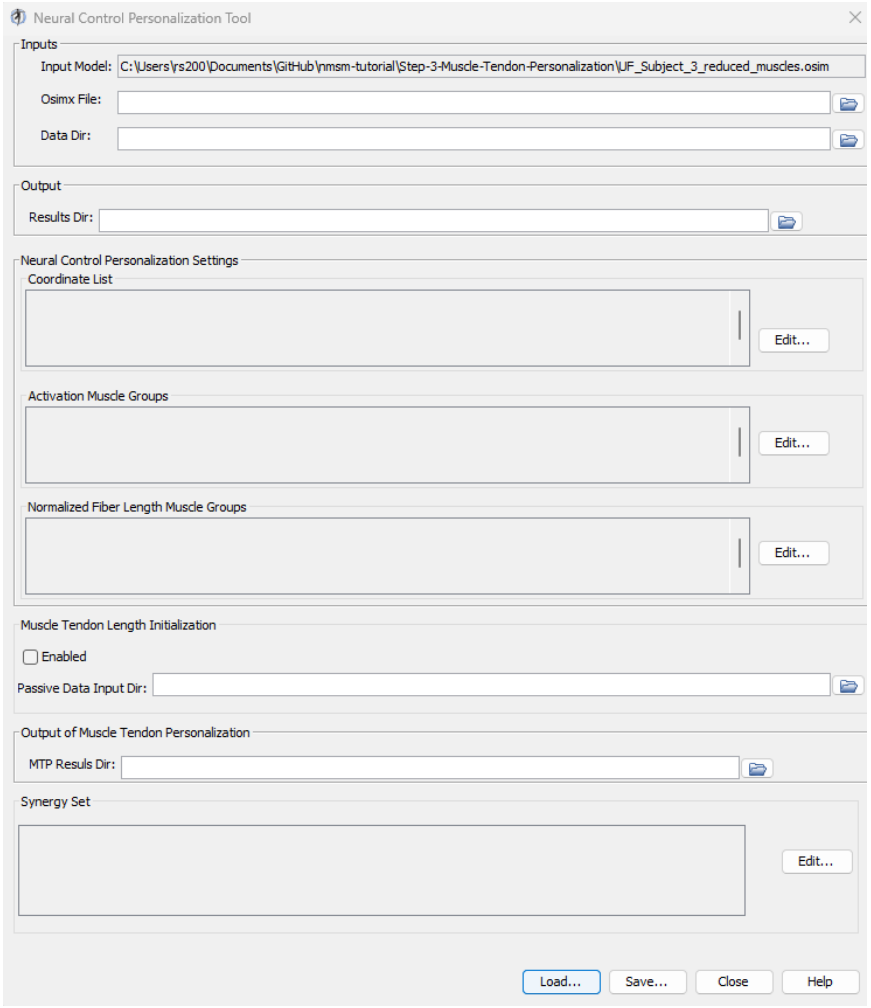
(**preprocessed\EMGData\gait_1.sto).** *These groups are only used in MTP.*

iv. Missing EMG Muscle Groups – Muscle groups that we **do not have** experimental EMG data for. *These groups are only used in MTP. *

c. These groups need to be created manually in a text editor such as Notepad++, but we have example groups for lower limb models in the *NMSM Article* download on SimTK: https://simtk.org/frs/?group_id=2397

Setting up an NCP settings file:

1. Activate the NMSM GUI in OpenSim by navigating to *Tools>User Plugins* and clicking **rcnlPlugin.dll.**
2. With **UF_Subject_3_reduced_muscles.osim** selected in the OpenSim GUI, navigate to *Tools>Model Personalization>Neural Control Personalization.*
    a. The following window should be opened:



3. Set the *input Osimx file* to be **mtpResults\UF_Subject_3_reduced_muscles_mtp.osimx**
4. Set the *data directory* to be **preprocessed**.
5. Set the *results directory* to be **NCPResults.**
6. For the *coordinate list*, select: (**hip_flexion_r, knee_angle_r, ankle_angle_r**).

7. For *activation muscle groups*, select (**HipFlexorsActivationGroupR, GlutmaxActivationGroupR, HamslatActivationGroupR, VasActivationGroupR, GasActivationGroupR**)
    a. Use filter term "activation" and click *select all shown*
8. For *normalized fiber length groups*, select (**GlutmaxNormalizedFiberLengthGroupR, HamsNormalizedFiberLengthGroupR, VasNormalizedFiberLengthGroupR, GasNormalizedFiberLengthGroupR**)
    a. Use filter term "fiber" and click *select all shown*
9. Keep *Muscle Tendon Length Initialization* **disabled**.
10. Set the *MTP results directory* to be **mtpResults**
11. Include **RightLeg** in the *synergy set* with **3 synergies**.
12. Save this settings file as **NCPSettings.xml**
13. Open **NCPSettings.xml** in a text editor of your choice and explore the settings file.

Running NCP:

1. Open MATLAB and open **runNCP.m** in your tutorial directory.
2. Open the project file (**Project.prj** inside your installation of nmsm-core.)
3. Run the MATLAB file **runNCP.m**

Post NCP Analysis:

1. Look through the plots created by the script. If everything was done correctly, there should be 3 plots.
    a. Plot 1 – Muscle Activations: Muscle activations produced by NCP synergies compared to the input MTP muscle activations.
    b. Plot 2 – Synergy Matching Quality: Variance accounted for (VAF) and root mean squared error (RMSE) for the synergy decomposition of muscle activations.
    c. Plot 3 – Joint Moment Matching: Joint moments generated by muscle forces compared to Inverse Dynamics joint moments.

Alternate NCP Formulations:

NCP's primary use is when you have muscle activations from MTP, but there are cases in which no muscle activation data are available, and you still want muscle activations to follow a synergy structure. This could happen because of trying to model joints without EMG data (lumbar for example), or when using datasets that didn't have any EMG data collected at all. In cases such as these, NCP also supports activation minimization. To experiment with activation minimization, turn off the activation tracking term, and turn on the activation minimization term. How do muscle activations and synergy activations from using activation minimization compare to those from using activation tracking? Is the moment matching better or worse with activation minimization?

This tutorial used 3 synergies. You may also experiment with using different numbers of synergies. How does changing the number of synergies affect the quality of muscle activation and joint moment tracking? What are the tradeoffs to using more or fewer synergies?