

Tutorial 4 – Neural Control Personalization

Tutorial Developer: Robert Salati, Rice Computational Neuromechanics Lab, Rice University

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 click **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:

The screenshot shows the 'Neural Control Personalization Tool' window. It has a title bar with a close button. The window is divided into several sections: 'Inputs' with fields for 'Input Model' (set to a path), 'Osimx File', and 'Data Dir'; 'Output' with a 'Results Dir' field; 'Neural Control Personalization Settings' containing three lists: 'Coordinate List', 'Activation Muscle Groups', and 'Normalized Fiber Length Muscle Groups', each with an 'Edit...' button; 'Muscle Tendon Length Initialization' with an 'Enabled' checkbox and a 'Passive Data Input Dir' field; 'Output of Muscle Tendon Personalization' with an 'MTP Results Dir' field; and 'Synergy Set' with an 'Edit...' button. At the bottom are 'Load...', 'Save...', 'Close', and 'Help' buttons.

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 **NCPResultsV1**.
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. Tip: The filter box at the top is very helpful to filter only activation groups

8. For *normalized fiber length groups*, select (**GlutmaxNormalizedFiberLengthGroupR**, **HamsNormalizedFiberLengthGroupR**, **VasNormalizedFiberLengthGroupR**, **GasNormalizedFiberLengthGroupR**)
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 **NCPSettingsV1.xml**
13. Open **NCPSettingsV1.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 section labelled **Run NCP V1**
 - a. With the section selected, press shift+enter to run a section.

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

Experiment with different numbers of synergies:

1. Create a copy of **NCPSettingsV1.xml** and name it **NCPSettingsV2.xml**
2. Open **NCPSettingsV2.xml** in a text editor of your choice.
3. Change `<results_directory>` to **NCPResultsV2**.
4. Inside `<RCNLSynergySet>`, change `<num_synergies>` to **4**.
5. Save this settings file as **NCPSettingsV2.xml**
6. Run the MATLAB section labelled **Run NCP V2**
 - a. With the section selected, press shift+enter to run a section.

Experiment with activation minimization:

1. Create a copy of **NCPSettingsV1.xml** and name it **NCPSettingsV3.xml**
2. Open **NCPSettingsV3.xml** in a text editor of your choice.
3. Change the `<results_directory>` to **NCPResultsV3**.
4. Inside `<RCNLCostTermSet>`, change `<is_enabled>` to **false** for the **activation_tracking** term.
5. Inside `<RCNLCostTermSet>`, change `<is_enabled>` to **true** for the **activation_minimization** term.
6. Save this settings file as **NCPSettingsV3.xml**
7. Run the MATLAB section labelled **Run NCP V3**
 - a. With the section selected, press shift+enter to run a section.