

An OpenSim Plugin for EMG-Constrained Static Optimization with Alternative Objective Functions

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The plugin is linked to the following open access publications; please cite them if using it for your research:

MacIntosh A.R., Keir, P.J. (2016) An open-source model and solution method to predict co-contraction in the finger. *Submitted* to Computer Methods in Biomechanics and Biomedical Engineering.

MacIntosh, Alexander. An open-source model and solution method to predict co-contraction in the index finger. Diss. 2014. ([MacSphere link to Thesis](#))

SimTK project: <https://simtk.org/home/projects/finger>

Overview

The plugin and analysis were completed with OpenSim 3.3 and Visual Studio 2013 on a 64-bit operating system.

Two changes were made to the OpenSim Static Optimization Analysis Tool to allow for:

- 1) Experimental EMG boundary constraints.
 - a. Frame by frame EMG activations are used as the initial guess in Static Optimization, and
 - b. Maximum and Minimum muscle activation are set by Experimental EMG \pm [EMG_control_range]
- 2) Alternative objective functions.
 - a. A detailed discussion regarding each objective function can be found in the thesis: “An open-source musculoskeletal model and EMG-constrained static optimization solution method to predict co-contraction in the index finger” [Link to Thesis](#)
 - b. Briefly, three objective functions have been tested:

- a. *Sum of Activation*- the standard method used in OpenSim

$$J = \sum_{m=1}^N (a_m)^p$$

where, J is the objective function, N is the number of muscles in the model, a_m is the activation of muscle m at a discrete time point, and p is the activation exponent.

- b. *Shift parameter*- Forster et al. (2004)

$$J = \sum_{m=1}^N (a_m - a_s)^p$$

where, J is the objective function, N is the number of muscles in the model, a_m is the activation of muscle m at a discrete time point, p is the activation exponent (squared), and a_s is the shift parameter that changes each muscles contribution to the objective function.

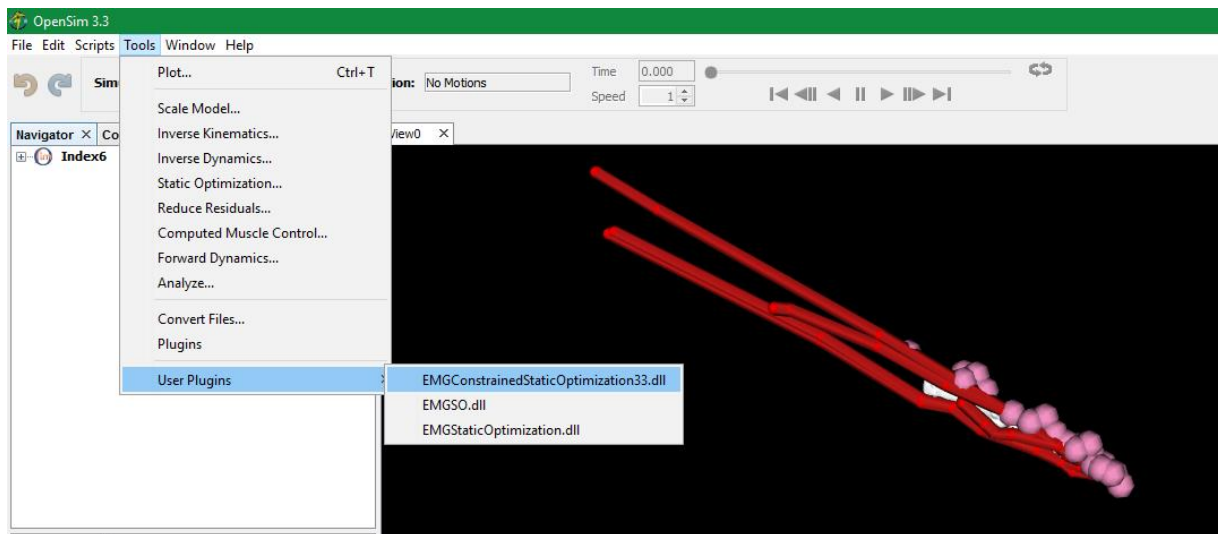
- c. *Entropy Assisted*- Jiang and Mirka (2007)

$$J = (1-W) \sum_{m=1}^N (a_m)^p + W \sum_{m=1}^N a_m \log a_m$$

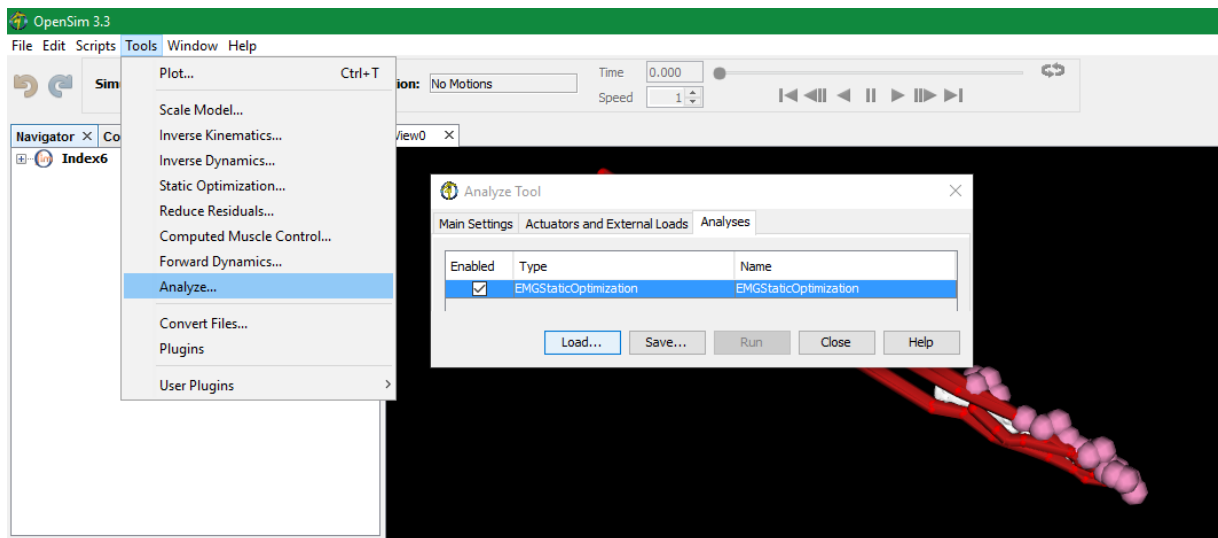
where, J is the objective function, N is the number of muscles in the model, a_m is the activation of muscle m at a discrete time point, p is the activation exponent (squared), and W is the co-contraction weight factor.

Analysis Plugin Description

After loading the plugin from: Tools >> User Plugins >> EMGConstrainedStaticOptimization33.dll



the EMGConstrainedStaticOptimization33 tool can be accessed through the Analyze Tool menu.



The following variables have been added to the Static Optimization Analysis Tool:

1. EMG_file
 - a. The name of the '.sto' file containing experimental EMG data. If a file name is provided, the EMG for each actuator in the file will be used.
2. EMG_control_range
 - a. The range of activation around the EMG signal that the optimizer is permitted to use.
Example: if normalized EMG Activation at $t_1 = 0.25$ and $\text{EMG_control_range} = 0.1$, then the permitted range of the optimizer is 0.15 - 0.35.
3. Objective_function

- a. The objective function used by the optimizer
 - i. 0 - Sum of Activation
 - ii. 1 - Shift parameter
 - iii. 2 - Entropy Assisted
- 4. Objective_actuator_names
 - a. Names of the actuators on which to perform the objective function. The key word 'All' indicates that the objective function should be performed for all bodies.
 - b. "All" places all muscles in the model in the order they appear in the model file.
 - c. "None" for list of muscle names makes the scalar array fill with default for every entry.
- 5. Default_objective_actuator_scalar
 - a. Relevant for objective functions 1 and 2.
 - b. Default scalar value per actuator. This is used by objective functions 1 and 2
 - i. In objective function 1: this value becomes the shift parameter for every muscle
 - ii. In objective function 2: this value becomes the weight factor (w) for every muscle
 - c. The default will be used for any actuator not specified in the Objective_actuator_names list
- 6. Objective_actuator_scalars
 - a. Relevant for objective functions 1 and 2.
 - b. In objective function 1: this value becomes the shift parameter for each muscle in the array Objective_actuator_names (in the corresponding position of the array)
 - c. In objective function 2: this value becomes the weight factor (w) for each muscle in the array Objective_actuator_names (in the correspond in position of the array)

The output files are the same as in the OpenSim Native Static Optimization Analysis.

Acknowledgements

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References

Forster, E., Simon, U., Augat, P., & Claes, L. (2004). Extension of a state-of-the-art optimization criterion to predict co-contraction. *Journal of Biomechanics*, 37(4), 577-581.

Jiang, Z., & Mirka, G. A. (2007). Application of an Entropy-Assisted Optimization Model in Prediction of Agonist and Antagonist Muscle Forces. Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

For full details please see: MacIntosh, Alexander. An open-source model and solution method to predict co-contraction in the index finger. Diss. 2014. ([MacSphere link to Thesis](#))