# MoBL-ARMS simulation tutorial

Last updated 2/10/2016.

This tutorial provides the files and instructions to replicate the simulations performed in the OpenSim modeling platform, as described in the following publication:

Saul KR, Hu X, Goehler CM, Daly M, Vidt ME, Velisar A, Murray WM. Benchmarking of dynamic simulation predictions in two software platforms using an upper limb musculoskeletal model. Computer Methods in Biomechanics and Biomedical Engineering. 2015; 18:1445-58. PMID:24995410

The original simulations were performed in the OpenSim 2.4 release. The MoBL-ARMS model is compatible up to version 3.3 as of the last update to this tutorial.

**Download simulation files from Simtk.org**

Go to <https://simtk.org/project/xml/downloads.xml?group_id=657> and download the **MoBL-ARMS Tutorial release**. In this release you will find the zipped folder ***MoBL-ARMS\_OpenSim\_tutorial\_33.zip***. Download this folder and use the files in the folder for your simulations and comparisons. These files will include this documentation document; a folder called CompareResults containing Excel files with the expected outputs of the simulation modules described below; and a folder called ModelFiles. The ModelFiles folder will contain a set of models used for these simulations, a Geometry folder containing the bone descriptions, and seven folders containing input data files.

**Running the models**

|  |  |
| --- | --- |
| There are seven different modules. Ctrl+click on the hyperlink below to get to the description for the module you want to run. | **Page** |
| [**1. Gravity-driven simulation without muscles**](#_Replicate_the_gravity-driven)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33*\CompareResults\Module\_1\_results\** | **3** |
| [**2. Gravity-driven forward simulation WITH ALL PASSIVE muscles**](#_Replicate_the_gravity-driven_1)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33* \CompareResults\Module\_2\_results\** | **4** |
| [**3. Gravity-driven forward simulation WITH ONLY IDENTICAL PASSIVE muscles**](#_Replicate_the_gravity-driven_3)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33*\CompareResults\Module\_3\_results\** | **5** |
| [**4. EMG-driven forward dynamic simulation**](#_Replicate_EMG-driven_forward_1)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33*\CompareResults\Module\_4\_results\** | **6** |
| [**5. Scaling and inverse kinematics**](#_Module_5._Scaling)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33* CompareResults \Module5\_results\IKreachfiltered.mot** | **8** |
| **[6. Computed muscle control analysis of a reach](#_Replicate_computed_muscle)**  **Compare to:**  **…\*MoBL\_ARMS\_OpenSim\_tutorial\_33*\CompareResults\Module6\_results\CMC\_results\_controls.sto** | **10** |
| [**7. CMC-driven forward dynamic simulation**](#_Module_7._CMC-driven)  **Compare to:**  **…\ *MoBL-ARMS\_OpenSim\_tutorial\_33*\CompareResults\Module7\_results\FDS\_states\_degrees.mot** | **11** |

**Comparison of outcomes**

Outcomes will be stored in a MOT-file or a STO-file that can be opened using the Plot Tool in OpenSim.Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. It will bring up a tickbox to choose the variable you would like to plot from among the columns in the datafile. Select the value(s) of interest (generally a joint or muscle name) and click *OK*. Click “*x-Quantity*” and another tickbox will come up. Choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the Comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

These files will also open in Excel if you prefer to compare plots in that program. The sampling rate can differ between simulations, but the curve should be overlapping the already existing curves.

**Technical recommendations and troubleshooting**

We suggest the use of Notepad++ for viewing or editing of .xml files used in the tutorial.

We recommend use of OpenSim version 3.3 64-bit.

Placing your models and model files in the \bin folder of the OpenSim install directory can improve visualization performance and simulation stability.

Refer to the above publication for average runtimes for each module. Please note that most modules only take a few minutes to run, except for the shoulder simulation in Module 4 which typically takes 45 minutes, and the CMC in Module 6 which takes approximately 4.5 hours to run.

If the scaled model bones appear malaligned or are absent following use of the scale tool, OpenSim may be looking for bone files in the wrong folder. Try saving, closing, and reopening the scaled model. Make sure your model is in the same folder as the Geometry folder. Alternatively, try placing all bone geometry files in the OpenSim geometry folder (under \Models in the OpenSiminstall directory), as this is the default location for Geometry files.

If you have additional analyses that you would like to run in concert with the forward dynamic simulations (such as MuscleAnalysis), we recommend performing forward dynamics without any analyses turned on, and then use the Analyze Tool on the resulting states output.

# Module 1.Gravity-driven simulation without muscles

In this module, we perform gravity-driven simulations of isolated joint motion to illustrate the behavior of the model in the absence of muscles, but in the presence of damping and joint restraint torques. This module illustrates the use of the forward dynamics tool.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\**MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model. *Open🡪 Model*“*MoBL\_ARMS\_module1\_nomuscles.osim*”
2. There are three gravity-driven simulations without muscles: isolated shoulder, elbow, and wrist movements (Table 1). Set up the joint angles in the tab “*Coordinates*” according to the simulation you want to run. Non-zero postures are highlighted in red.
3. After you have set up the joint angles of the starting posture, set this starting posture to default using: *Poses*🡪*Set Default* in the same tab. If the Poses button is not visible, you may need to adjust the window size of the coordinates tab in order to view it.
4. Open Forward Dynamics Tool. *Tools*🡪*Forward Dynamics*
5. Upload the provided settings file. Load 🡪 “MoBL\_ARMS\_module1\_Setup.xml”

This file has made the following modifications to the default settings:

1. The time range for the forward simulation was set from 0 to 5 seconds.
2. The precision output was set to 20 (default is 8).
3. Specify Output Directory. Specify the Prefix and Directory for the output to whatever you choose.
4. Click Run to run the simulation. Remember the pose you want to start with should be set to the default pose before you start the simulation. “Poses 🡪 Set Default”

**Table 1. Types of simulations with associated joint angles used to performthe gravity-driven simulation without muscles.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type of Simulation | elv\_angle | shoulder\_elv | shoulder\_rot | elbow\_flexion | pro\_sup | deviation | flexion |
| Shoulder Elevation | 0  Locked | 30  Unlocked | 0  Locked | 0  Locked | 0  Locked | 0  Locked | 0  Locked |
| Elbow Flexion | 0  Locked | 0  Locked | 0  Locked | 40  Unlocked | 0  Locked | 0  Locked | 0  Locked |
| Wrist Flexion | 0  Locked | 0  Locked | 0  Locked | 90  Locked | 90  Locked | 0  Locked | 0  Unlocked |

Note: All joint angles are in degrees

**Comparison of outcomes**

Outcomes will be stored in a MOT-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select the joint angle you simulated and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:** *…\ MoBL-ARMS\_OpenSim\_tutorial\_33\CompareResults\Module\_1\_results\*

# Module 2. Gravity-driven forward dynamic simulation WITH ALL PASSIVE muscles

In this module, we perform gravity-driven simulations of isolated joint motion with all muscles included in the model, but only permitted to produce passive forces. This module illustrates the use of the forward dynamics tool.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model. *Open🡪 Model*

“*MoBL\_ARMS\_module2\_4\_allmuscles.osim*”

1. There are three gravity-driven simulations with all muscles included in the model, generating passive force only: isolated shoulder, elbow, and wrist movements (Table 2). Set up the joint angles in the tab “*Coordinates*”according to the simulation you want to run. Non-zero postures are highlighted in red.
2. After you have defined the joint angles of the starting posture, set this starting posture to default using: *Poses*🡪*Set Default* in the same tab. If the Poses button is not visible, you may need to adjust the window size of the coordinates tab in order to view it.
3. Open Forward Dynamics Tool. Tools 🡪 Forward Dynamics
4. Upload the provided settings file. Load 🡪 “MoBL\_ARMS\_module2\_Setup.xml”

This file has made the following modifications to the default settings:

1. The time range for the forward simulation was set from 0 to 5 seconds.
2. The precision output was set to 20 (default is 8).
3. “Solve for equilibrium for actuator states” was checked.
4. Specify Output Directory. Specify the Prefix and Directory for the output to whatever you choose.
5. Click Run to run the simulation. Remember the pose you want to start with should be set to the default pose before you start the simulation. “Poses 🡪 Set Default”

**Table 2. Types of simulations with associated joint angles used to perform the gravity-driven forward simulation with all muscles and with only identical muscles.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type of Simulation | elv\_angle | shoulder\_elv | shoulder\_rot | elbow\_flexion | pro\_sup | deviation | flexion |
| Shoulder Elevation | 0  Locked | 30  Unlocked | 0  Locked | 0  Locked | 0  Locked | 0  Locked | 0  Locked |
| Elbow Flexion | 0  Locked | 0  Locked | 0  Locked | 40  Unlocked | 0  Locked | 0  Locked | 0  Locked |
| Wrist Flexion | 0  Locked | 0  Locked | 0  Locked | 90  Locked | 90  Locked | 0  Locked | 0  Unlocked |

Note: All joint angles are in degrees

**Comparison of outcomes**

Outcomes will be stored in a MOT-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select the joint angle you simulated and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:** *…\ MoBL-ARMS\_OpenSim\_tutorial\_33\Compare results\Module\_2\_results\*

# Module 3. Gravity-driven forward dynamic simulation WITH ONLY IDENTICAL PASSIVE muscles

In this module, we perform gravity-driven simulations of isolated joint motion with only those muscles included which are identical between the SIMM and OpenSim implementations of the MoBL\_ARMS model; muscles produce only passive forces. In the context of the associated manuscript, these simulations were intended to isolate the effects of differences in muscle model implementation between the platforms. This module illustrates the use of the forward dynamics tool.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model.*Open🡪 Model*  
   “*MoBL\_ARMS\_module3\_samemuscles.osim*”
2. There are three gravity-driven simulations with only muscles that do not differ between the SIMM and OpenSim implementations, generating passive force only: isolated shoulder, elbow, and wrist movements (Table 2). Set up the joint angles in the tab “*Coordinates*”according to the simulation you want to run. Non-zero postures are highlighted in red.
3. After you have defined the joint angles of the starting posture, set this starting posture to default using: *Poses*🡪*Set Default* in the same tab. If the Poses button is not visible, you may need to adjust the window size of the coordinates tab in order to view it.
4. Open Forward Dynamics Tool. Tools 🡪 Forward Dynamics
5. Upload the provided settings file. Load 🡪 “MoBL\_ARMS\_module3\_Setup.xml”

This file has made the following modifications to the default settings:

1. The time range for the forward simulation was set from 0 to 5 seconds.
2. The precision output was set to 20 (default is 8).
3. “Solve for equilibrium for actuator states” was checked.
4. Click Run to run the simulation. Remember the pose you want to start with should be set to the default pose before you start the simulation. “Poses 🡪 Set Default”

# 

**Comparison of outcomes**

Outcomes will be stored in a MOT-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select the joint angle you simulated and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:** *…\ MoBL-ARMS\_OpenSim\_tutorial\_33\Compare results\Module\_3\_results\*

# Module 4. EMG-driven forward dynamic simulation

In this module, we perform EMG-driven simulations of isolated joint motion with all muscles included and activated according to measured EMG for each movement. This module illustrates the use of the forward dynamics tool in conjunction with applied EMG activations to actuators.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model. *Open🡪 Model*“*MoBL\_ARMS\_module2\_4\_allmuscles.osim*”.
2. There are three EMG-driven simulations with muscles activated according to measured EMG: isolated shoulder, elbow, and wrist movements (Table 3). Set up the joint angles in the tab “*Coordinates*”according to the simulation you want to run. Non-zero postures are highlighted in red.
3. After you have defined the joint angles of the starting posture, set this starting posture to default using: *Poses*🡪*Set Default* in the same tab. If the Poses button is not visible, you may need to adjust the window size of the coordinates tab in order to view it.
4. Open Forward Dynamics Tool. *Tools*🡪*Forward Dynamics*
5. Upload the provided settings file. Load 🡪 “MoBL\_ARMS\_module4\_Setup\_shoulder.xml”, “MoBL\_ARMS\_module4\_Setup\_elbow.xml”, or “MoBL\_ARMS\_module4\_Setup\_wrist.xml”

This file has made the following modifications to the default settings:

1. The time range for the forward simulation was set from 0 to 6.52 seconds.
2. The precision output was set to 20 (default is 8).
3. “Solve for equilibrium for actuator states” was checked.
4. In the Forward Dynamics Tool, check that the loaded EMG data in “*Input* 🡪 *Controls*” is correct.   
   for shoulder:  
   “*…\MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module4\_OSimEMGDrivenSimulation\controls\_EMG\_shoulder.sto*”;  
   for elbow:  
   “*…\MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module4\_OSimEMGDrivenSimulation\controls\_EMG\_elbow.sto*”;  
   for wrist:  
   “*…\MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module4\_OSimEMGDrivenSimulation\controls\_EMG\_wrist.sto*”;
5. Specify Output Directory. Specify the Prefix and Directory for the output to whatever you want.
6. Click *Run* to run the simulation. Remember the pose you want to start with should be set to the default pose before you start the simulation. “Poses 🡪 Set Default”

**Table 3. Types of simulations with associated joint angles used to performthe EMG-driven simulations.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Type of Simulation | elv\_angle | shoulder\_elv | shoulder\_rot | elbow\_flexion | pro\_sup | deviation | flexion |
| Shoulder Elevation | 0  Locked | 20  Unlocked | 0  Locked | 0  Locked | 0  Locked | 0  Locked | 0  Locked |
| Elbow Flexion | 0  Locked | 25  Locked | 0  Locked | 15  Unlocked | 0  Locked | 0  Locked | 0  Locked |
| Wrist Flexion | 0  Locked | 60  Locked | 0  Locked | 80  Locked | 30  Locked | 10.64  Unlocked | -22.413  Unlocked |

Note: All joint anglesare in degrees

**Comparison of outcomes**

Outcomes will be stored in a MOT-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select the joint angle you simulated and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay. Note: The wrist simulation has two output angles: flexion and deviation.

**Compare to: “***…\MoBL-ARMS\_OpenSim\_tutorial\_33\CompareResults\Module\_4\_results\*

# **Module 5. Scaling and inverse kinematics**

In this module, we perform scaling and inverse kinematics to obtain joint angles from marker positions measured for a forward reaching movement, in preparation for performing a computed muscle control analysis (Module 6). This module illustrates the use of the scale and inverse kinematics tools.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model. *Open 🡪 Model*“*MoBL\_ARMS\_module5\_scaleIK.osim*”.
2. Open Scale Model Tool. *Tools*🡪*Scale Model*
3. Upload the provided settings file. Load 🡪“ MoBL\_ARMS\_module5\_Scale\_Setup.xml”

This file has made the following modifications to the default settings:

1. Checked “Preserve mass distribution during scale” box
2. Checked “Marker data for measurements” box
3. Loaded “Static.trc” file under scale model heading
4. Set Average measurement between times 7.845 and 8.525
5. Checked “Adjust Model Markers” box
6. Loaded “Static.trc” file for Marker data for static pose
7. Set Average measurement between times 7.845 and 8.525
8. Leave the rest of the settings to default. Click Save if you would like to save these settings to a setup file for future simulations.
9. Click *Run* to run the simulation.
10. A new scaled model will appear in the model view window, with a corresponding new model listed in the navigator window. To save the model, go to the File menu and click “*Save as*”. Save the model to a folder of your choosing with the name “*MoBL\_ARMS\_module5\_scaled.osim*”
11. In the “*Coordinates*” tab, set r\_x=90 degrees, r\_y=0 degrees, r\_z=10 degrees, deviation = 0 degrees and flexion = 0 degrees, and lock these coordinates. This reflects known experimental postures; the wrist was braced in neutral for this trial.
12. With the scaled model as the current model, open Inverse Kinematics Tool. *Tools*🡪*Inverse Kinematics*
13. Upload the provided settings file. Load 🡪“ MoBL\_ARMS\_module5\_IK\_Setup.xml”

This file has made the following modifications to the default settings:

1. Loaded marker data for trial: “*…\MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module5\_ScaleIK\reach.trc*”
2. Click Save if you would like to save these settings to a setup file for future simulations.
3. Click *Run* to run the simulation.
4. A new motion named “*Results”* will appear under motions in the navigator. Right click and save as… “*…\IKreach.mot*” to a folder of your choosing.
5. Filter this offline using Matlab. We have provided a Matlab filter:

“*…\MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module5\_ScaleIK\filter.m*”

This will create a file called*…\IKreachfiltered.mot*

**Comparison of outcomes**

Outcomes will be stored in a STO-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select one or more joint angles for comparison and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:** “*…\MoBL-ARMS\_OpenSim\_tutorial\_33\CompareResults \Module\_5\_results\IKreachfiltered.mot*”

# Module 6. Computed muscle control analysis

In this module, we perform a computed muscle control analysis (CMC) of a forward reaching movement. This module illustrates the use of the computed muscle control tool. It can be performed using the provided inputs (as described below) or using the output from Module 5. If so, make sure your input folders are the output folders you defined in Module 5.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model from ModelFiles directory. *Open 🡪 Model*

“*MoBL\_ARMS\_module6\_7\_CMC.osim*”. The coordinate r\_z should be locked at 10 degrees. The rest of the coordinates should be unlocked, but these coordinates do not need to be set to a default value.

1. Open Computed Muscle Control Tool. *Tools*🡪*Computed Muscle Control*
2. Upload the provided settings file. Load 🡪“ MoBL\_ARMS\_module6\_Setup.xml”

This file has made the following modifications to the default settings:

1. “Filter kinematics” was checked and set the value to 6Hz.
2. Loaded tracking tasks and selected input file:  
   “*…\MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module6\_CMC\CMC\_Tasks.xml*”
3. “Actuator constraints” was checked and selected input file:

“*…\MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module6\_CMC\CMC\_ControlConstraints.xml”*

1. Precision was set to 20 (default is 8).
2. Changed the *“Maximum number of steps”* to 300,000,000 and the *“Integrator error tolerance”* to 0.0005 (under the “Integrator Settings” tab).
3. Set time range to process from 0.59 to 4.35
4. Load desired kinematics to “*Main Settings* 🡪*Desired Kinematics*”. Browse to select data file from the input file folder or the output from Module 5:  
   “*…\MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module6\_CMC\IKreachfiltered.mot*”
5. Specify Output Directory. Specify the Prefix and Directory for the output to whatever you choose.
6. Click Save if you would like to save these settings to a setup file for future simulations.
7. Click *Run* to run the simulation.

**Comparison of outcomes**

Outcome controls will be stored in a STO-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select one or more muscles for comparison and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:**

“…*\MoBL-ARMS\_OpenSim\_tutorial\_33\CompareResults \Module\_6\_results\CMC\_results\_states.sto*”

# Module 7. CMC-driven forward dynamic simulation

In this module, we perform CMC-driven simulations of a forward dynamic simulation with all muscles included and activated according to CMC-derived controls (see Module 6). This module illustrates the use of the forward dynamics tool in conjunction with applied CMC-derivedcontrols to actuators. It can be performed using the provided controls and inputs (as described below) or using the output from Module 6. If so, make sure your input folders match the output folders you defined in Module 6.

1. Once you have downloaded the *MoBL-ARMS\_OpenSim\_tutorial\_33* folder from <https://simtk.org/project/xml/downloads.xml?group_id=657>, the models are in the folder:

*…\ MoBL-ARMS\_OpenSim\_tutorial\_33\ModelFiles.*

1. In OpenSim, load the Upper Extremity Model. *Open🡪 Model*“*MoBL\_ARMS\_module6\_7\_CMC.osim*”.
2. The initial posture joint angles associated with the simulation for this model are in Table 4. Set up the joint angles in the tab “*Coordinates*”to run this simulation.
3. After you have defined the joint angles of the starting posture, set this starting posture to default using: *Poses*🡪*Set Default* in the same tab. If the Poses button is not visible, you may need to adjust the window size of the coordinates tab in order to view it.
4. Open Forward Dynamics Tool. *Tools*🡪*Forward Dynamics*
5. Upload the provided settings file. Load 🡪“ MoBL\_ARMS\_module7\_Setup.xml”

This file has made the following modifications to the default settings:

1. Unchecked “*Solve for equilibrium for actuator states*”.
2. Time range for the forward simulation was from 0.62 to 3.99 seconds.
3. Precision was set to 20 (default is 8).
4. Loaded CMC control data from Module 6:

“…*MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module7\_CMCDrivenForwardSimulation\CMC\_Reach8\_controls.sto*”

1. Loaded initial conditions created an abbreviated version of states output from Module 6:

*“…MoBL\_ARMS\_OpenSim\_tutorial\_33\ModelFiles\InputFiles\_module7\_CMCDrivenForwardSimulation\CMC\_Reach8\_states\_abbrev.sto*”

Note: If you prefer to use the output you created from Module 6, you will need to prepare this file. Open the states file from your CMC output folder and delete all rows of data except the first line which corresponds with the initial time. Save this file as “*CMC\_Reach8\_states\_abbrev.sto*”.

1. Specify Output Directory. Specify the Prefix and Directory for the output to whatever you choose.
2. Click Save if you would like to save these settings to a setup file for future simulations.
3. Click *Run* to run the simulation. Remember the pose you want to start with should be set to the default pose before you start the simulation. “Poses 🡪 Set Default”

**Table 4. The joint angles used to performthe CMC-driven forward dynamic simulations**.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Type of Simulation | elv\_angle | shoulder\_elv | shoulder\_rot | elbow\_flexion | pro\_sup | deviation | flexion | R\_z |
| CMC-driven simulation | -38.262  Unlocked | 13.313  Unlocked | -8.068  Unlocked | 97.677  Unlocked | 25.440  Unlocked | 0  Locked | 0  Locked | 10  Locked |

Note: All joint angles are in degrees

**Comparison of outcomes**

Outcomes will be stored in a MOT-file. Load your results in Plot Tool by clicking “*y-Quantity*”. Select “*Load file*” and browse to your output. Select one or more joint angles for comparison and click *OK*. Click “*x-Quantity*”, choose “*time”* and click *OK*. Click “*Add*” to plot the curve. Without closing the window, click “*y-Quantity*” again and this time load the corresponding comparison output file. Repeat the process above to plot the comparison curves. They should overlay.

**Compare to:**

“…*\MoBL-ARMS\_OpenSim\_tutorial\_33\CompareResults\Module\_7\_results\FDS\_states\_degrees.mot*”