# Tutorial 1 - Joint Model Personalization

The Joint Model Personalization (JMP) tool optimizes joint parameters, body scaling, and marker placement to minimize IK marker distance errors. Reducing inverse kinematics marker distance errors reduces downstream errors in calculated inverse dynamic joint moments, muscle–tendon lengths and velocities, muscle moment arms, and ultimately muscle activations and forces. These quantities are used by subsequent Model Personalization tools.

The inputs to JMP are a scaled generic OpenSim model, kinematic marker data from one or more motion trials, and a JMP settings file. This tutorial will explore the creation of JMP settings file using both the NMSM Pipeline GUI in OpenSim, and by directly editing the settings file in a text editor.

## Before running JMP:

The primary input to a JMP run is a scaled generic OpenSim model. JMP is designed for small adjustments to model parameters, so large scaling adjustments should still be done with OpenSim's *Scale Model* Tool.

1. Open **RCNL2023.osim** in the OpenSim GUI.
2. Open the *Scale Model* Tool.
3. Load the settings file **ScaleSettings.xml.**
4. Run the scale tool
5. With the new model **UF_Subject_3_v2** selected in the *Navigator* window, click on the *Coordinates* window.
6. Lock **knee_adduction_r** and **knee_adduction_l**
   a. The knee adduction angle models varus/valgus deformity and doesn't change much during gait. The scale tool modifies this angle using static pose data, and then we don't change it afterwards.
7. Save the scaled model as **UF_Subject_3_scaled.osim.**

To get the most accurate personalization, JMP prefers that "functional joint trials" are used, in which a single joint is moved through its full range of motion. We can visualize these motions using the OpenSim *Inverse Kinematics Tool*.

1. With **UF_Subject_3_scaled.osim** selected in the OpenSim GUI, open the *Inverse Kinematics Tool.*
2. Load the settings files **IKSettingsRightAnkle.xml** and **IKSettingsRightKnee.xml**

# Setting up a JMP settings file:

1. Activate the NMSM GUI in OpenSim by navigating to *Tools>User Plugins*, and click **rcnlPlugin.dll**
2. Open **UF_Subject_3_scaled.osim** in the OpenSim GUI
3. With **UF_Subject_3_scaled.osim** selected in the OpenSim GUI, navigate to *Tools>Model Personalization>Joint Model Personalization*
   a. The following window should be opened:
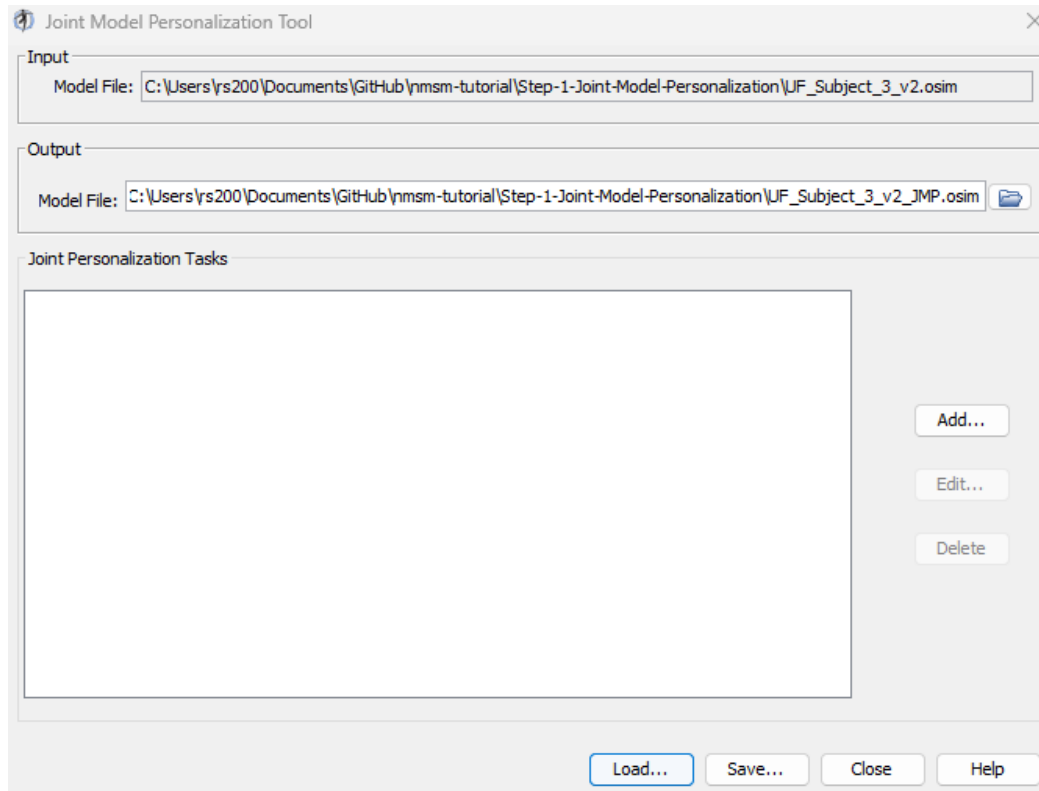


4. Rename the output model file to **UF_Subject_3_scaled_JMPV1.osim**
5. Create a new JMP Task:
   a. Name this task **Scale Hips**
   b. Select the *Markers File* to be **MarkerFiles\GaitTrial_markers.trc**
   c. Add a new body to this task:
      i. Body name: **Pelvis**
      ii. Scale body: **Yes**
      iii. Move markers: **Y-, Z-axes**
6. Create a new JMP Task:
   a. Name this task **Right Knee**
   b. Select the *Markers File* to be **MarkerFiles\RightKnee_markers.trc**
   c. Add a new joint to this task.
      i. Joint name: **knee_r**

   ii. Parent frame translation: **None**

   iii. Parent frame rotation: **X-, Y- axes**

   iv. Child frame translation: **None**

   v. Child frame rotation: **X-, Y- axes**

7. Create a new JMP Task:

 a. Name this task **Right Ankle**

 b. Select the *Markers File* to be **MarkerFiles\ RightAnkle_markers.trc**

 c. Add a new joint to this task.

   i. Joint name: **ankle_r**

   ii. Parent frame translation: **None**

   iii. Parent frame rotation: **X-, Y- axes**

   iv. Child frame translation: **None**

   v. Child frame rotation: **None**

 d. Add a new joint to this task.

   i. Joint name: **subtalar_r**

   ii. Parent frame translation: **None**

   iii. Parent frame rotation: **Y- axis**

   iv. Child frame translation: **None**

   v. Child frame rotation: **Y- axis**

8. Create a new JMP Task:

 a. Name this task **Move markers**

 b. Select the *Markers File* to be **MarkerFiles\GaitTrial_markers.trc**

 c. Add a new body to this task:

   i. Body name: **femur_r**

   ii. Scale body: **No**

   iii. Move markers: **Y-, Z-axes**

 d. Add a new body to this task:

   i. Body name: **tibia_r**

   ii. Scale body: **No**

   iii. Move markers: **Y-, Z-axes**

9. Save the settings file as **JMPSettingsV1.xml**

10. Open **JMPSettingsV1.xml** in a text editor of your choice, and explore the document

11. Inside your `<JMPTask>` **Scale Hips**, copy and paste:

```
<marker_names>R_Thigh_Lateral R_Thigh_Superior R_Thigh_Inferior R_Asis
L_Asis Sacral</marker_names>
```

12. Inside your `<JMPTask>` **Right Knee**, copy and paste:

```
<marker_names>R_Thigh_Lateral R_Thigh_Superior R_Thigh_Inferior
R_Shank_Superior R_Shank_Inferior R_Shank_Lateral</marker_names>
```

13. Inside your `<JMPTask>` **Right Ankle**, copy and paste:

```
<marker_names>R_Shank_Superior R_Shank_Inferior R_Shank_Lateral R_Heel
R_Midfoot_Superior R_Midfoot_Lateral</marker_names>
```

14. Inside your `<JMPTask>` **Move Markers**, copy and paste:

```
<marker_names>R_Thigh_Lateral R_Thigh_Superior R_Thigh_Inferior
R_Shank_Superior R_Shank_Inferior R_Shank_Lateral</marker_names>
```

## Running JMP:

1. Open MATLAB and open **runJMP.m** in your tutorial directory.
2. Open the project file (**Project.prj** inside your installation of nmsm-core.)
3. Ensure MATLAB is set up to use multi-processing, not multi-threading:
   a. In the bottom left of MATLAB, click the parallel processing icon, and click *parallel preferences*.
   b. In the drop down menu for *Default Profile*, select **Processes**.
4. Run the MATLAB section labelled **Run JMP V1**
   a. With the section selected, press shift+enter to run a section.
   b. This JMP run will take a few minutes to run.

## Post JMP Analysis:

1. In the OpenSim GUI, open **UF_Subject_3_scaled_JMPV1.osim**.
2. Visually inspect this new model compared to **UF_Subject_3_scaled.osim**. What changed?
3. Analyze the plots created by **runJMP.m**
   a. How do the post-JMP marker errors compare to the `<max_allowable_error>` specified in the settings file?
   b. Note that the biggest reductions in error are around peaks. If the error was already low, JMP doesn't make a big difference.

## Experiment with simultaneous JMP runs:

The previous JMP run personalized all joints sequentially from the ankle upwards. This has the benefit of a quicker runtime but has more error because the personalization of one joint can negatively affect the personalization of another joint. This can be addressed by personalizing all joints simultaneously. Simultaneous JMP runs take much longer to run but have lower error at the end.

To set up a simultaneous JMP run, you need to normalize all marker trials to 101 time points, and concatenate all of them together into one file. This has already been done in **MarkerFiles\ AnkleKneeGaitConcatenated_markers.trc.**

1. With **UF_Subject_3_scaled.osim** selected in the OpenSim GUI, open a new JMP GUI window.
   a. This allows us to use the previous JMP run as a starting point for a new JMP run.
2. Rename the output model file to **UF_Subject_3_scaled_JMPV2.osim**
3. Create a new JMP Task:
   a. Name this task **All Joints**
   b. Select the *Markers File* to be **MarkerFiles\ AnkleKneeGaitConcatenated_markers.trc**
   c. Add a new joint to this task.
      i. Joint name: **ankle_r**
      ii. Parent frame translation: **None**
      iii. Parent frame rotation: **X-, Y- axes**
      iv. Child frame translation: **None**
      v. Child frame rotation: **None**
   d. Add a new joint to this task.
      i. Joint name: **subtalar_r**
      ii. Parent frame translation: **None**
      iii. Parent frame rotation: **Y- axis**
      iv. Child frame translation: **None**
      v. Child frame rotation: **Y- axis**
   e. Add a new joint to this task.
      i. Joint name: **knee_r**
      ii. Parent frame translation: **None**
      iii. Parent frame rotation: **X-, Y- axes**
      iv. Child frame translation: **None**
      v. Child frame rotation: **X-, Y- axes**
   f. Add a new body to this task:
      i. Body name: **Pelvis**
      ii. Scale body: **Yes**
      iii. Move markers: **Y-, Z-axes**
   g. Add a new body to this task:
      i. Body name: **femur_r**
      ii. Scale body: **No**
      iii. Move markers: **Y-, Z-axes**
   h. Add a new body to this task:
      i. Body name: **tibia_r**
      ii. Scale body: **No**
      iii. Move markers: **Y-, Z-axes**
4. Save this settings file as **JMPSettingsV2.xml**.
5. Open **JMPSettingsV2.xml** in a text editor of your choice.

6. Inside your `<JMPTask>` **All Joints**, copy and paste:

```
<marker_names> R_Asis L_Asis Sacral R_Thigh_Lateral R_Thigh_Superior
R_Thigh_Inferior R_Shank_Superior R_Shank_Inferior R_Shank_Lateral R_Heel
R_Midfoot_Superior R_Midfoot_Lateral </marker_names>
```

7. This JMP run takes too long to run for the workshop, so premade results are in **CompletedSettingsFiles**

8. To see premade results from a full simultaneous simulation, copy and paste **CompletedSettingsFiles\JMPSettingsV2.xml** and **CompletedSettingsFiles\UF_Subject_3_scaled_JMPV2.osim** into your working directory. Then run the MATLAB section labelled **Run JMP V2**.