**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.

1. **Before running JMP:**
2. Open the OpenSim model “UF\_Subject\_3\_scaled.osim**”** in the OpenSim GUI.
3. Run the Inverse Kinematics (IK) tool on the model using the marker file “GaitTrial\_markers\_jmp.trc”
   1. Keep all weights equal to 1. When JMP runs IK, it also uses weights of 1.
4. Open “GaitTrial\_markers\_jmp.trc” in the OpenSim GUI with “File>Preview Experimental Data”
5. Sync the experimental marker motion with your generated IK Result and inspect the motion
6. **Questions:**
   1. What is the average marker RMS error throughout the gait cycle?
   2. Which markers have the highest error. What do you think is causing this error?
      1. Hint, think about where these markers are on the body. Are they placed over bone landmarks?
   3. What are some methods you think could reduce this error?
7. **Setting up a JMP settings file:**
8. Activate the NMSM GUI in OpenSim by navigating to “Tools>User Plugins”, and click “rcnlPlugin.dll”
9. With “UF\_Subject\_3\_scaled.osim” selected in the OpenSim GUI, navigate to “Tools>Model Personalization>Joint Model Personalization”
   1. The following window should be opened:

A screenshot of a computer

AI-generated content may be incorrect.

1. Rename the output model file to “[working\_directory]\UF\_Subject\_3\_scaled\_JMPV1.osim”
2. Click “Add” to open a window to create a JMP Task.
   1. Name this task “Scale Hips”
   2. Select the marker file to be “GaitTrial\_markers\_jmp.trc”
   3. Click “Add” under the “Bodies in this Task” window.
      1. Select the body name to be “pelvis”, check “Scale Body”, and allow markers to move in the Y-direction.
3. Create a new JMP Task:
   1. Name this task “Right Knee”
   2. Select the marker file to be “GaitTrial\_markers\_jmp.trc”
   3. Click “Add” under the “Joints in this Task” window.
      1. Select the joint name to be knee\_r.
      2. Under parent frame, check only rotation in the X- & Y-directions.
      3. Under child frame, check only rotation in the X- & Y- directions.
4. Create a new JMP Task:
   1. Name this task “Left Knee”
   2. Select the marker file to be “GaitTrial\_markers\_jmp.trc”
   3. Click “Add” under the “Joints in this Task” window.
      1. Select the joint name to be knee\_l.
      2. Under parent frame, check only rotation in the X- & Y-directions.
      3. Under child frame, check only rotation in the X- & Y- directions.
5. Save the settings file as “JMPSettingsV1.xml”
6. Open up the JMP settings file in a text editor of your choice, and explore the document
7. **Questions:**
   1. What elements could you directly edit in the GUI?
   2. Were there any elements that show up in the file that you didn’t specify in the GUI?
   3. What is the default value given for max allowable error? What does this term represent in terms of the JMP optimization?
   4. Explore the optimization settings at the bottom of the settings file. How would changing these parameters affect the optimization result?
   5. The settings file has 3 separate tasks. This means that each joint is personalized sequentially instead of all at once. What errors might this lead to?
8. **Running JMP:**
9. Open MATLAB and create a new script called runJMP.m in your JMP tutorial directory.
10. In the script, type: JointModelPersonalizationTool("JMPSettingsV1.xml")
11. Ensure MATLAB is set up to use multi-processing, not multi-threading:
    1. In the bottom left, of matlab click the parallel processing icon, and click “parallel preferences”.
    2. In the drop down menu for Default Profile, select Processes.
12. Press Run
    1. This JMP run will take a few minutes to run.
13. **Questions:**
    1. Take note of the cost function value and step size at the last few iterations for each task. Might this JMP run benefit from changing some of the numerical method convergence parameters? If so, which parameters should be changed? (Recall question 2d)
14. **Post JMP Analysis:**
15. In the OpenSim GUI, open the new model created by JMP.
16. Re-run IK following the steps in Section 1 above.
17. Compare the marker errors of the post-JMP model to those of the pre-JMP model.
18. **Questions:**
    1. How do the RMS errors compare between the pre and post JMP model? Is this an expected result?
    2. What is the maximum marker error for the post-JMP model? How does this number compare to the max allowable error parameter for your JMP runs?
    3. What markers have the most error? Is this the same or different compared to the pre-JMP model?
19. **Experiment with different JMP formulations:**
20. With the post-JMP model selected in the OpenSim GUI, open a new JMP GUI window.
    1. This allows us to use the previous JMP run as a starting point for a new JMP run.
21. Rename the output model file to “[working\_directory]\UF\_Subject\_3\_scaled\_JMPV2.osim”
22. Create a new JMP Task:
    1. Name this task “Move Markers”
    2. Select the marker file to be “GaitTrial\_markers\_jmp.trc”
    3. Click “Add” under the “Bodies in this Task” window.
       1. Select the body name to be “femur\_r”, check “Scale Body”, and allow markers to move in the X- & Y-direction.
    4. Click “Add” under the “Bodies in this Task” window.
       1. Select the body name to be “tibia\_r”, check “Scale Body”, and allow markers to move in the X- & Y-direction.
23. Save this settings file as “JMPSettingsV2.xml” and run it in MATLAB.
24. Visually compare the new model created by this JMP run to the model created by JMPSettingsV1.
25. **Questions:**
    1. What direction did the markers move? Does this make sense? Recall your answers to questions 1b & 1c.
    2. Which markers have the most error? Did this change from the previous JMP run?
26. **Change max allowable error:**
27. Open JMPSettingsV1.xml in a text editor of your choice.
28. Rename the output model file to “[working\_directory]\UF\_Subject\_3\_scaled\_JMPV3.osim”
29. Change the max allowable error term to be 0.02 instead of 0.01.
30. Save this settings file as JMPSettingsV3.xml and run it in MATLAB
31. Run inverse kinematics on this new model.
32. **Questions:**
    1. How do the marker errors compare to the JMP model with a smaller max allowable error?
    2. How did the optimization convergence change after raising the max allowable error?