ME/BIOE 481: Dynamic walking model simulation

Updated: February 18, 2021, Mariana E. Kersh

1 Critical info

• Due date: February 26, 2021 - 11:59PM (US Central standard time)

• Part 1: 10 points. This is an individual section of the assignment to be completed on PrairieLearn.

• Part 2: 10 points. You may work in pairs or triplets. Instructions are below.

2 Introduction

In this exercise you will be given several Passive Dynamic Walker Models and an arena with obstacles. The goal of the exercise is to maximize the distance the walkers can travel on increasingly challenging terrain by adjusting the model's parameters. You will use the OpenSim graphical user interface (GUI) to adjust component properties, visualize dynamic simulations, and make plots of your simulation results. Options for a Matlab-based iteration of your model is also given (this may prove useful for quickly updating your model parameterss).

3 Software Required

1. Requires OpenSim 4.1 software (https://opensim.stanford.edu)

2. Base model files for this exercise are included in the OpenSim 4.1 distribution and are found in your OpenSim directory; OpenSim/4.1/Code/Matlab/Dynamic Walker Challenge/.

3. Additional model files and .m files are found on the course web page (link to box folder). Requires 64-bit version of Matlab.

4 Explore the OpenSim GUI and Model

In this section, you will familiarize yourself with the OpenSim GUI and explore the editable properties of the walker and environment. You will use the GUI to examine the bodies, joints, contact geometry, and forces that make up the model. In the following sections, you will learn how to adjust the model properties to create your own robust walker.

4.1 Launch the OpenSim Program

Launch the OpenSim application. You will see multiple information panels and an empty main Visualizer Window. You can learn more about the Graphical User Interface (GUI) in the OpenSim User's Guide. Here is a helpful webpage: https://simtk-confluence.stanford.edu/display/OpenSim/Tutorial+1+-+Intro+to+Musculoskeletal+Modeling

4.2 Explore the model components

In the OpenSim GUI, select File>Open Model to open the WalkerModelTerrain.osim. You can find this in your OpenSim directory: OpenSim/4.1/Code/Matlab/Dynamic Walker Challenge/.

• The View panel is used to control the model's visual display. You can move the view camera around the model using a combination of mouse and trackpad gestures.

• In the Navigator panel on the left side of the screen, use the + icon to expand the list of model components. Explore the individual components in the model by clicking on them in the Navigator Panel.

– As you click on each component, scroll through the component's properties in the Property Editor panel underneath the Navigator panel.

– Observe each of the following:

– Bodies: A platform, pelvis, thigh, and shank bodies with mass, inertia, and visual geometry.

– Joints: A Planar joint connecting the model with the Platform and Pin joints between all the segments' pin joints.
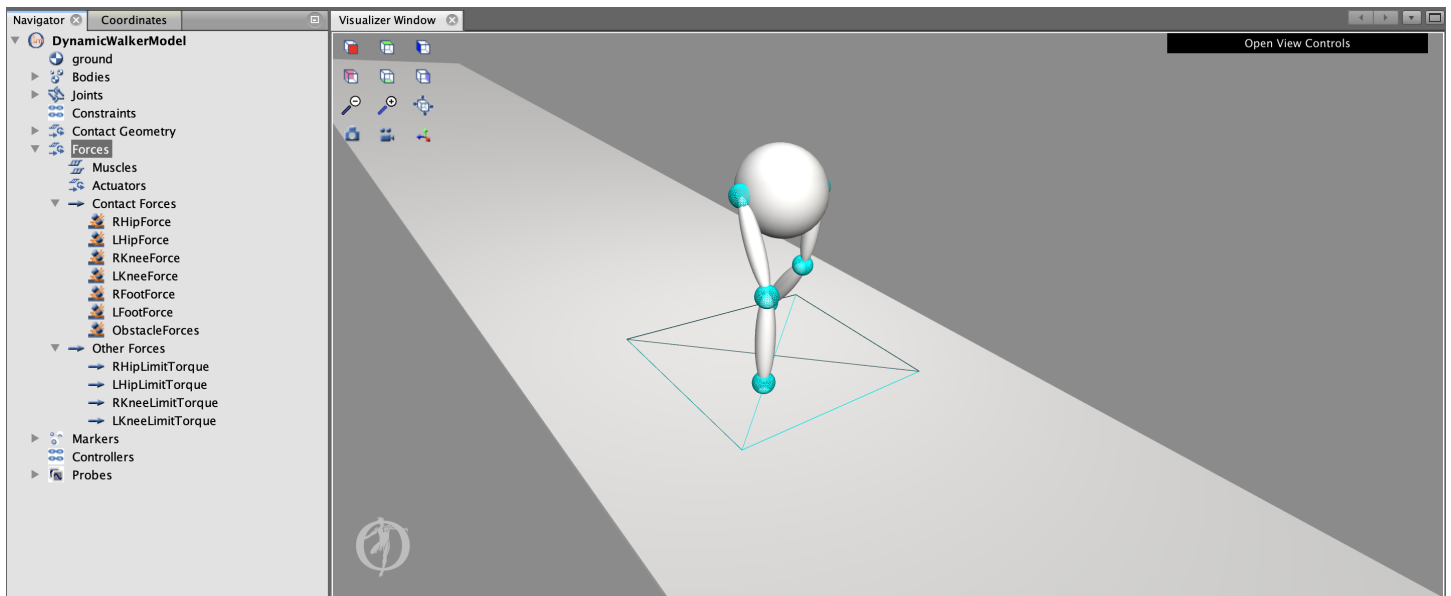
Figure 1: View of OpenSim GUI with Navigator panel shown

- – Contact Geometry: Contact spheres and a contact half space (plane), which are used to generate contact forces.
- – Contact forces: Forces that are computed and applied due to the interaction between contact geometries.
- – Other Forces: Coordinate limit forces, which enforce the desired range of motion of the joints. Springs and other forces.

- The Coordinates panel lists the current values of the model's generalized coordinates.

  - – The values of the coordinates (in meters or degrees) can be changed with the sliders or by entering a value in the left text box.
  - – The initial coordinate speeds (in meters/second or radians/second) are used as the initial conditions forward simulations. These can be set in the speed text box on the right hand side of each row.
  - – The value of a coordinate can be locked by toggling the lock icon.
  - – To reset the model to the default pose, select Poses>Default. You can also uses the Poses menu to change the default pose and add custom poses.

5 Simulate and Visualize the Walker

In this section, you will run a dynamic simulation of the model, visualize the resulting motion, plot the output, and save a movie of the motion using the OpenSim GUI.

5.1 Run the Forward Tool

Before you run the forward tool, go to the Coordinates tab in the left panel and choose a set of initial coordinate values and coordinate velocities for your simulation.

- Select Tools>Forward Dynamics from the top menu in the GUI

- In the Time Pane, set the Time Range to Process from 0 to 2 seconds

- In the Output Pane, append a directory called FWD to the currently listed directory. Do this by adding "" to the current output directory. You can leave all the other settings at their default value.

- To quickly set up future runs of the forward tool, save your settings to a file (e.g., SetupForward.xml) by clicking the Save button. You can then load the setupforward.xml which will autopopulate the time range and the directory. This is only moderately helpful here and not an essential step. It saves you the time to update the time rage to 0 and include the "FWD" directory.

- Click the Run button to begin the simulation.

- Close the tool.

5.2 Visualize the motion

After running the forward tool, three storage files (.sto) are written to the output directory specified with the time history of the control signals and the model states. The model state histories, which for this model contain the coordinate values and velocities, are automatically loaded into the program (Results) and can be accessed in the Navigator panel under Motions.

- If you wish to run several motions with different starting conditions, make sure to Rename the motion from the default name Results by right clicking on the item in the Navigator and changing the name (e.g. Trial1).

At the top middle section of the GUI, the blue movie controls can be used to playback and visualize the results. On the left hand side, the playback speed can be adjusted with the arrow icons or by entering a value in the textbox. In the center, you can use the control icons to play a movie forward or backwards, either continuously, or frame-by-frame.

- Hit the blue play button to visualize the results from your forward simulation.

5.3 Create a plot or movie in the GUI

- In the Navigator panel under Motions, double click a motion to make it the current motion (bold name).

- Once you have results, you can plot them in OpenSim:

  – Instructions on plotting data can be found here: https://simtk-confluence.stanford.edu/display/OpenSim/Plot+Window

- How to make a video of OpenSim results:

  – On the left side of the Visualizer Window, click the video camera icon. Set the time and speed of your motion using the view controls.
  – Play the resulting motion (Note: you can pause the movie before completion if you want a specific interval). You can pause and rotate the model and play again to get a movie with two views of the walker.
  – Click the video camera icon again. This will end the capture and turn the camera icon blue again.
  – A dialog will appear. Type in your desired name for your movie file and hit the Save button.

6 Pro-tips

- In the configuration of the Forward Tool, the initial conditions of the system will be taken from the listed values in the Coordinates panel.

- Changing the joint locations to length the segments will not change the visual object in the GUI. To change the visual object, open the Body set, click on the body, and click on ... for the Displayer element in the Properties panel.

- Use the keyboard shortcuts (Ctrl+Z for undo, Ctrl+Y for redo) or the orange and blue arced arrows in the Top Left section of the GUI to manage your model changes.

7 Optional

For those so inclined, it's possible to update the model using Matlab.

1. To do so you need to install the Matlab-OpenSim API environment. Follow the instructions here (steps 1-7) https://simtk-confluence.stanford.edu:8443/display/OpenSim/Scripting+with+Matlab

2. In the files for the DynamicWalkerChallenge there is a folder called UserFunctions. Locate the file called DesignMain-Starter.m

3. Note that the code (line 52) is a relative path to the model you will be modifying (by default it is set to run the WalkerModelTerrain.osim that exists in the OpenSim files. Update this to the osim file with feet for parts 3-4.

4. To modify the model pose or speeds, update lines 34-45.

ME/BIOE 481: Dynamic walking model simulation

Updated: February 18, 2021, Mariana E. Kersh

Name: _____

Name: _____

Name: _____

Critical info

- Due date: February 26, 2021 - 11:59PM (US Central standard time)

- Part 1: 10 points. This is an individual section of the assignment to be completed on PrairieLearn.

- Part 2: 15 points. You may work in pairs or triplets. Instructions are below.

1. Define the following terms in your own words: (0.5 points each)
   (a) passive walker
   (b) cost of transport

2. Let's consider that the goal of walking is anterior translation of the center of mass (pelvis translation in the x direction). Modify the initial pose of the walker model (WalkerModelTerrain.osim) to maximize this goal (it may or may not end up looking like human walking!).

   - Create a template forward dynamics simulation file by loading the forward dynamics tool. Set the time to run from 0 to 2 and append the "FWD" directory at the output file as a folder to save your results. Click Save and save this file as setupFWD.xml. Take note of where this saved. Click close.

   - Check that your model is aligned to the default pose (coordinates - click Poses - select default). Select the forward dynamics option under tools. Click load and open the setupFWD.xml that you just saved. Add "trial1" to the output directory.

   - While keeping velocities constant, modify the initial pose of the model to achieve what you think would be a best initial pose for walking by adjusting the coordinates in the coordinate screen. Click Run in the Forward dynamics simulation menu. In the Navigator panel, you should now have a "results" file under Motions. Right click and rename this Trial1 (or whichever trial you are on).

   (a) (1 pt) Try at least 6 iterations with each trial given a unique name (e.g. Trial2, Trial3). Keep a list of what each trial represents.

Trial	Parameter Value					
	Pelvis Ty	Pelvis Tx	Right Hip	Left Hip	Right Knee	Left Knee
1						
2						
3						
4						
5						
6						

   (b) Details on how to plot results in OpenSim are here: https://simtk-confluence.stanford.edu/display/OpenSim/Plot+Window. In OpenSim, plot the anterior translation of the center of mass of the pelvis. In the plot tool, select Y-results. Select the trial and choose "/jointset/PelvisToPlatform/Pelvistx/value" for the output variable. In the x-quantity select "Time". Update the curve name to the trial being plotted. Repeat this for your 6 trials.

   (c) (2 pt) Plot the anterior translation of the hip for your six trials. Which trial resulted in the greatest anterior translation of the hip? What variable(s) were changed for this trial?
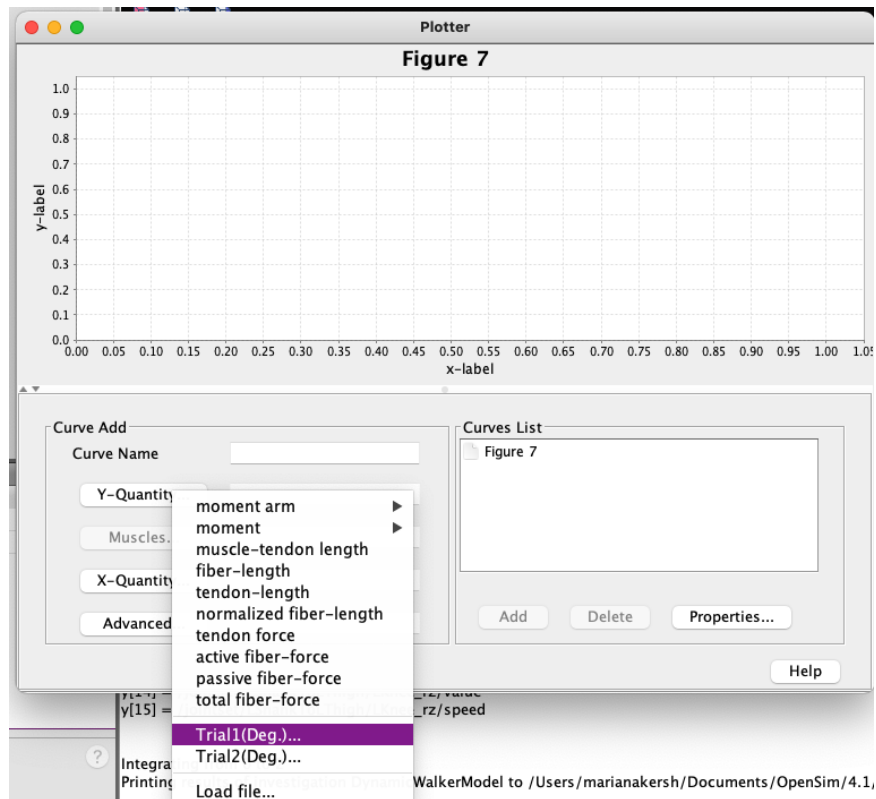
Figure 2: Plotting results

3. This model has trouble maintaining knee extension during stance. We can help by adding a force component to the model that will always act to extend the knee. Second, we can add a foot to the model. Load the model called WalkerModelTerrainKneeMagnetWithFeet.osim from Box (see link on course webpage). Note that you need to save the .osim file and the ThinHalfCylinder100mmby50mm.obj file in the same folder to load the model with feet.

   • Create a template forward dynamics simulation file by loading the forward dynamics tool. Set the time to run from 0 to 2 and append the "FWD" directory at the output file as a folder to save your results. Click Save and save this file as setupFWD.xml. Take note of where this saved. Click close.

   • Check that your model is aligned to the default pose (coordinates - click Poses - select default). Select the forward dynamics option under tools. Click load and open the setupFWD.xml that you just saved. Add "trial1" to the output directory.

   • While keeping velocities constant, modify the initial pose of the model to achieve what you think would be a best initial pose for walking by adjusting the coordinates in the coordinate screen. Click Run in the Forward dynamics simulation menu. In the Navigator panel, you should now have a "results" file under Motions. Right click and rename this Trial1 (or whichever trial you are on).

   (a) (1 pt) Try at least 6 iterations with each trial given a unique name (e.g. Trial2, Trial3). Keep a list of what each trial represents.

Trial	Parameter Value					
	Pelvis Ty	Pelvis Tx	Right Hip	Left Hip	Right Knee	Left Knee
1						
2						
3						
4						
5						
6						

   (b) (2 pts) Plot the anterior translation of the hip for your six trials. Which trial resulted in the greatest anterior translation of the hip? What variable(s) were changed for this trial?

4. Now, while using the default pose, modify the velocities of the segments and joints to maximize the anterior translation of the walker.

(a) (1 pt) Try at least 6 iterations with each trial given a unique name (e.g. Trial2, Trial3). Keep a list of what each trial represents.

Trial	Parameter Value					
	Pelvis Ty	Pelvis Tx	Right Hip	Left Hip	Right Knee	Left Knee
1						
2						
3						
4						
5						
6						

(b) (2 pts) Plot the anterior translation of the hip for your six trials. Which trial resulted in the greatest anterior translation of the hip? What variable(s) were changed for this trial?

5. Another option to achieve stable walking is to modify the model itself. Try a few iterations with each trial given a unique name (e.g. Trial2, Trial3).

(a) (1 pt) Keep a list of what each trial represents by making a table similar to those above. Note what parameters you changed. Below are a few options for modification.

- Modify the mass and inertia parameters of the bodies. The mass and inertia properties of the body can be accessed through the Navigator panel. Open the bodies group by clicking on the + icon and selecting a body from the list. In the properties window you can select the mass, the mass center location, and the six unique elements of the inertia matrix for the body. The mass center is the location of the mass center from the body origin measured in the body reference frame and the inertia values are the inertia of the body about the body center of mass measured in the body reference frame.

- Modify the segment length in the joints. Access the joint properties in the Joints set in the Navigator panel. The length of the segment is set by the adjacent joints. To change the length of the right thigh segment, edit the translation property of the appropriate RightThighoffset frame (located under Bodies > RightThigh in the Navigator).

(b) (2 pts) Plot the anterior translation of the hip for your trials. Which trial resulted in the greatest anterior translation of the hip? What variable(s) were changed for this trial?

6. (2 pts) Make a movie of your best result. Convert this to a gif (https://convertio.co). Give your model a name and post the following to the chatroom called assignment2-results

(a) Your model name

(b) Your team members names (so we can give you credit!)

(c) A gif of your result