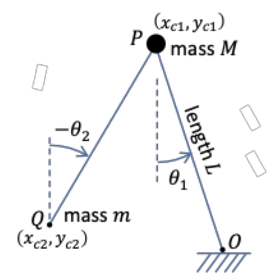
Homework 04

1. Implement the simplest walking model and find a periodic gait. The file `simplestwalkingstep` provides equations of motion, event detection, the step-to-step transition, and even sample animation code.
   A. Produce a simulation similar to the rimless wheel. Use parameter values alpha = 0.3, gamma = 0.03 (3% downward slope), and try initial guess $x = [0.3 - 0.3 - 0.3 - 0.25]$.
   B. Add a test for energy conservation, similar to the rimless wheel.
   C. Using the initial guess, try to find a periodic motion (limit cycle) that includes stance phase ending at heelstrike, and the step-to-step transition to yield the new state.

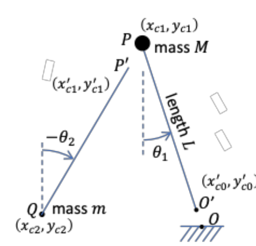
2. Use the embedded constraint method to produce a drop-in replacement for the equations of motion for the simplest walking model, which are provided in symbolic form in the sample code. The foot O is attached to the ground origin with a hinge joint, and the swing leg also rotates about the pelvis P with a hinge joint. Both legs are of length L, and have orientations measured counter-clockwise with respect to vertical. The corresponding pose Jacobian looks like this:



$$J = \begin{bmatrix} -L\cos q_1 & 0 \\ \cdots & 0 \\ 1 & 0 \\ \cdots & \cdots \\ -L\sin q_1 & L\sin q_2 \\ 0 & 1 \end{bmatrix}$$

   The only masses are point masses M and m; the legs have no mass or inertia.
   A. Produce a state-derivative function, which should have identical inputs and outputs to the sample fsimpwalk2. Demonstrate it by comparing one-step simulations against the symbolic function.
   B. Produce a test for your function, to ensure it provides similar behavior to fsimpwalk2.
   C. Produce an energy conservation test.

3. Use the explicit constraint method to produce a drop-in replacement for the equations of motion for the simplest walking model. Here the segments should be treated as separate, but then require a constraint Jacobian to enforce the joints. The matrix should look like this:



$$C = \begin{bmatrix} 1 & 0 & L\cos q_1 & 0 & 0 & 0 \\ 0 & 1 & \cdots & \cdots & \cdots & \cdots \\ -1 & 0 & 0 & 1 & -L\cos q_2 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \end{bmatrix}$$

(Note that the centers of mass are located at the ends of the segments, and the constraints describe how the segment ends are connected together.)

A. Produce a state-derivative function, which should have identical inputs and outputs to the sample fsimpwalk2. Demonstrate it by comparing one-step simulations against the symbolic function.
B. Produce a test for your function, to ensure it provides similar behavior to fsimpwalk2.
C. Produce an energy conservation test.

4. The problems above are challenging, and deserve additional clues or clarifications. Please file GitHub issues to ask for hints or corrections.