ME459 Final Project Proposal

Problem statement: Standing balance is an inherently unstable task that requires control of rotational and translation movement. Humans use the interaction force between the ground and the foot to help manage the fluctuating accelerations of the body that can and do occur in standing balance. The commonly used model for how the legs and feet interact with the ground, and in turn this interaction force, is a double inverted pendulum with torque actuated knee and ankle joints (see Figure 1).

In order to help elucidate the control strategy used during standing balance, this model can be simulated using a forward dynamics approach across a range of joint and limb positions to help identify. This project is to create a model of the double inverted pendulum, establish constraining algorithms based on the physical boundaries of the system (joint angles, torques, angular accelerations, etc.), and identify all possible joint configurations that can be considered stable standing when controlled with a forward dynamic approach. (This last step may require more time than I have now, and will require substantial computational power from Euler)
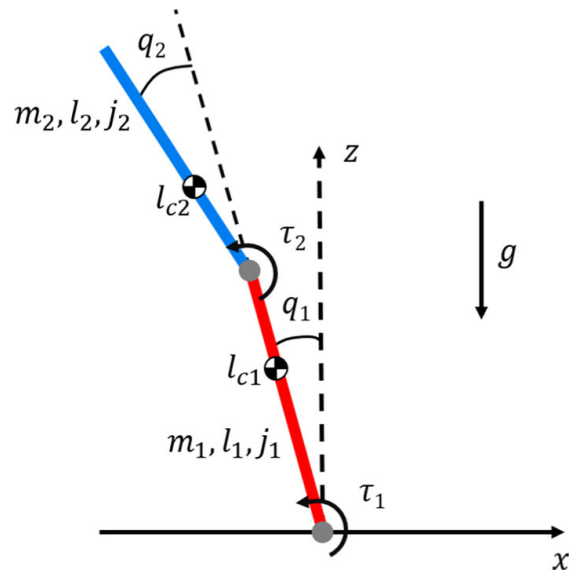

Figure 1: Double Inverted Pendulum

Motivation/Rationale: My research is with the Neuromuscular Coordination Laboratory in the Kinesiology school under Dr. Kreg Gruben. In his prior work, Dr. Gruben has established through experimental data that there is an intersection point of the interaction ground force in the z-axis that appears to be consistent across standing and walking balance subjects in a variety of situations. This could imply that there is a mechanically optimal configuration that your body controls too related to the z-axis intersection. Dr. Gruben has undertaken a small-scale analysis of using the forward dynamic model similar to the project I have proposed here, however it was not executed on the scale possible if I utilize the power of c and the Euler clusters. A comprehensive sweep of all possible configurations would provide substantial data and evidence for our lab to continue to move forward with the investigation into the Z intersection point.

How you plan to go about it:
1. In c, develop a program that will determine if a modeled inverted double pendulum in a given configuration is considered "stable" based on constraining physical parameters
2. Expand this approach to include a forward dynamics control – identify if the configuration is stable, and if not, can the configuration be returned to stability with simple constant ankle and knee joint torques
3. Extend approach to consider if configuration can be returned to stability with limited angular velocity and acceleration (may include LQR control to identify what the optimal strategy from a work-reduction approach would be)
4. Once identification algorithm is complete, implement it in a sweeping function that assesses all possible physical configurations to identify ranges of "successful" configurations
5. *Add function to identify the Z-intersect of the configurations deemed stable (need to discuss this approach with PI further)

ME459 aspects the proposed work draws on: bulleted list, be brief. Talk about what concepts we learned in ME459 you will be hitting on in your project.

- Creating functions that can input, modify and return variables
- Utilizing functions that can call other functions
- Dynamic memory allocation when performing the sweeping function to manage speed and memory consumption
- Processing of large data sets
- Interacting with formatted user input and rejecting incorrect values

How you will demonstrate what you accomplished:

Be able to determine if a configuration is stable or not – if stable identify the resultant joint angles when within the stability tolerance and the angular velocity of the COM of the limbs, the overall joint torques required in knee and ankle, and the magnitude and direction of resultant ground interaction force*. If not stable, identify the values that were out of the stability tolerance range during the forward dynamic control to attempt to keep stability. Have baseline stable positions captured from prior studies that can be used as a reference and validation

Team member[s]:
- Name: Jackson Fox
- Email: jmfox8@wisc.edu
- Home department: Mechanical Engineering
- Status: Graduate Student
- Partner: NA

Deliverables:

Minimum - Program(s) that can take an input lower leg configuration as modeled by a double inverted pendulum and return the stability status (stable/unstable) and the relevant information about the system in that configuration, as described above.

Long Term Deliverable – the above program as well as a large data set of configurations based on a comprehensive optimization through the various configuration positions to identify all stable postures for analysis of Z-intersect behavior.

Other remarks:

NA