2.74: Bio-inspired Robotics
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1. Title: Optimal stride length for climbing stairs

2. Project goal

There are a lot of stairs at MIT. Some, like the steps outside lobby 7, have short steps that form a very shallow incline angle. Others, like the stairwell in building 16, have taller steps that form a much steeper incline angle. Idealized physics would suggest that the energy required to climb up either set of stairs is simply the person's weight times the height of the stairs. However, given that normal walking without an incline still takes energy, biomechanics would suggest that the energy needed to climb the stairs is not so straightforward. In addition to the question of *energy*, there is also the question of *speed*—for a shallow set of stairs, climbing at max speed is essentially running, whereas for a steep set of stairs, the movement is slower but gains vertical height at a steeper rate. Some stairs are designed to be architecturally aesthetic, but others (such as emergency exits) would benefit from optimizing the efficiency for people (or robots) to climb. In this project, we propose to examine the effect that incline angle and step size have on climbing speed and energy efficiency.

We plan to test two main hypotheses:

1. There is an optimal **incline angle** that maximizes both the energy efficiency (least amount of work done per unit height) and vertical speed of the climber within a motor torque limit. Steeper inclines will require higher peak torques, whereas shallower inclines will result in more steps per unit height.

2. For a similar reason, there is also an optimal **step height** to maximize the energy efficiency and vertical speed of the climber. Higher step heights also

include skipping steps (ie, longer stride lengths).

3. Experimental Setup

The robot will consist of two legs (each with 2 degrees of freedom) supported by a counterweight on the gantry. The virtual spring and dampers of each leg will be tuned and held constant, and the control parameters will be the commanded stride trajectory based on the size and incline of the steps. The performance metric will primarily be the work done by the motors per unit height that the robot climbs, but we will also look at the vertical speed of the robot.

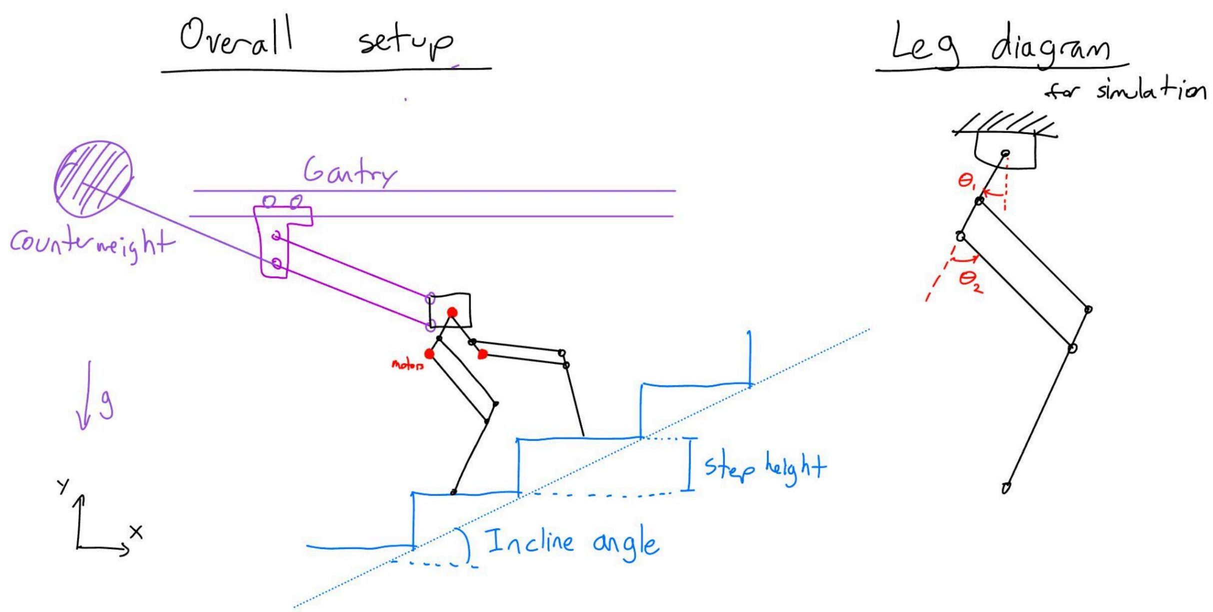

Fig 1a: schematic of the robot's degrees of freedom and testing rig. Parameters will be changed by swapping out different sets of steps and inclines and changing the stride trajectory accordingly. Fig 1b: We will be using the legs used in lab.

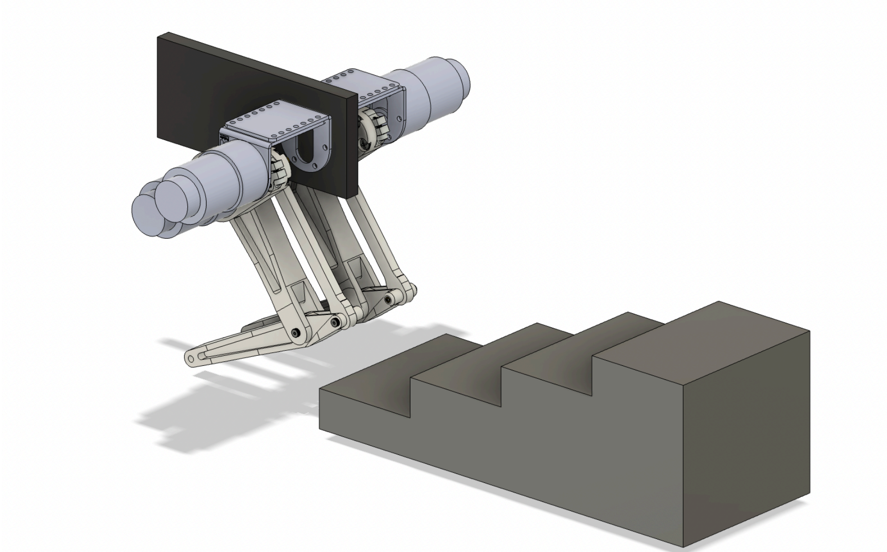

Fig 2: Legs CAD. The black piece between the legs represents where the legs will be fixed to the gantry. We will design the stairs hardware to be more modular so that we can test more geometries easier.

The system will be modeled in matlab using rigid body simulations. Contact with the ground will be modeled as a no-slip point contact where the compliance in the ground represents the foot compliance.

4. Expected results

We expect to find a trend for a given staircase where strides too long require large bursts of high torque, while too short are “easier” but require many steps per unit height climbed. We expect a similar trend for step height, where taking longer strides will require high torques, but taking shorter strides requires more impacts. Therefore, there should be some incline angle and stride length to optimize the work needed to climb a given height.

5. Project schedule

- Provide team schedule and deadlines for the rest of the semester (Final presentations will be on 12/5 and 12/7, the exhibition is 12/9).
- Provide the role of each member each week.
- Make sure you finish hardware before the Thanksgiving (11/19)
- Where to meet? How often will you meet?

Team Meetings: Mondays 2:30 - 5 PM and Tuesdays 2 - 4 PM
Extra Meeting Time when needed: Fridays 9 AM - 12 PM or after 4 PM

	Simulation	**Simulation**	**Hardware**	**Hardware**
Week	Andy	Brenda	Seigo	Brandon
10/28 - 11/1	Setup simulation for 2 legs + controller	Setup simulation for 2 legs + controller	Modify lab leg CAD. Design varying stairs on CAD	Modify lab leg CAD. Design varying stairs on CAD
11/4 - 11/8	Adding gantry+ counterweight to dynamics. Walk cycle: bezier loop + phase	Adding gantry+ counterweight dynamics. Walk cycle: bezier loop + phase	Design varying stairs on CAD and 3D print. Assemble everything.	Design varying stairs on CAD and 3D print. Assemble everything.
11/11 - 11/15	Test controller on hardware. Gather 1st set of data. Get TA or Professor's input.	Test controller on hardware. Gather 1st set of data. Get TA or Professor's input.	Implement controls	Implement controls
11/18 - 11/22	Continue running tests and analysis. Begin poster formatting.	Continue running tests and analysis. Begin poster formatting.	experiment. Begin poster formatting.	experiment. Begin poster formatting.
thanks giving				
12/2 - 12/4	Finish poster/ presentation	Finish poster/ presentation	Final touches/buffer	Final touches/buffer