The Robomechanics Lab

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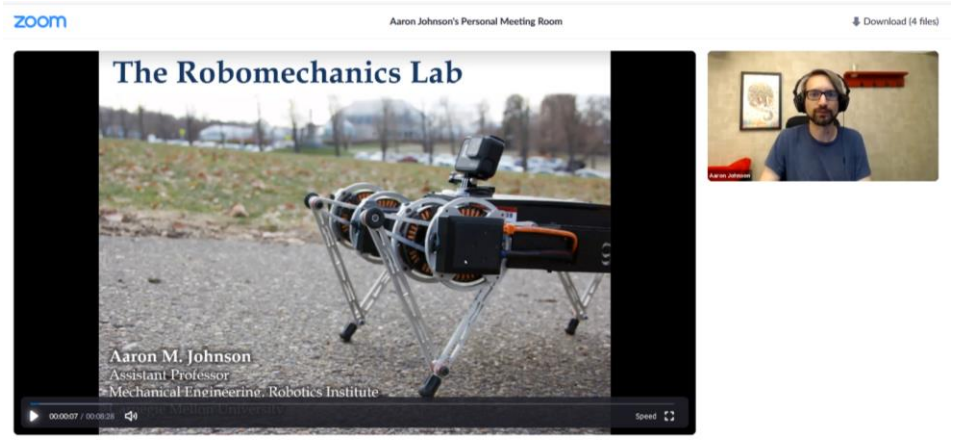
Lab Overview

Fall 2020 Overview Video:



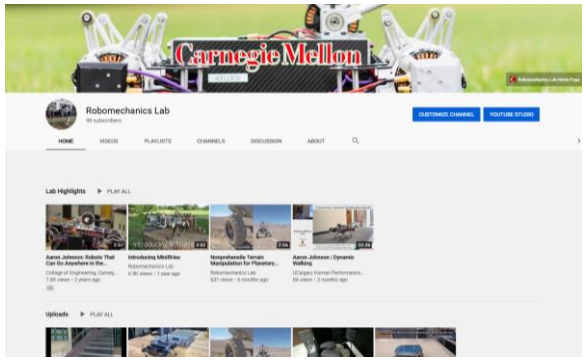
https://cmu.zoom.us/rec/share/us0rBKz28EpIRa_g-k7tR_MmIaW8eaa8hHMX-vEJmhs4mZrj8lktZ5VCMwo5_ZQ1

Spring 2021 Seminar:

https://www.youtube.com/watch?v=rtx5DV-TfKg

YouTube Channel with more talks and research videos:

https://www.youtube.com/channel/UCKD78aZAsdB9-JTwrt6Q1KA



Fall 2022 Projects

robomechanics.net
amj1@cmu.edu

- I am an MS-R or CIT-H student. How do I work with you?
  1. Look through this document at the advertised projects.
  2. Read the recommended paper.
  3. After that, email me with:
     - Your resume
     - Why you want to work on that project (~2 sentences)
     - Availability the week before or after the start of the semester to setup a meeting
- Do you advise MS-C, MS-AS, or other non MS-R students?
  - Yes, but priority is for MS-R slots first.
- If I don't join your lab, can we still work together?
  - Yes! I teach Robot Dynamics & Analysis in the fall
- Do you fund MS-R students?
  - No. I wish I could!

Project 1: Locomotion on Muddy Terrain

- What are the best driving strategies for rough, muddy terrain?
- How can we plan safe paths through terrain?

- Skills: Some ROS experience

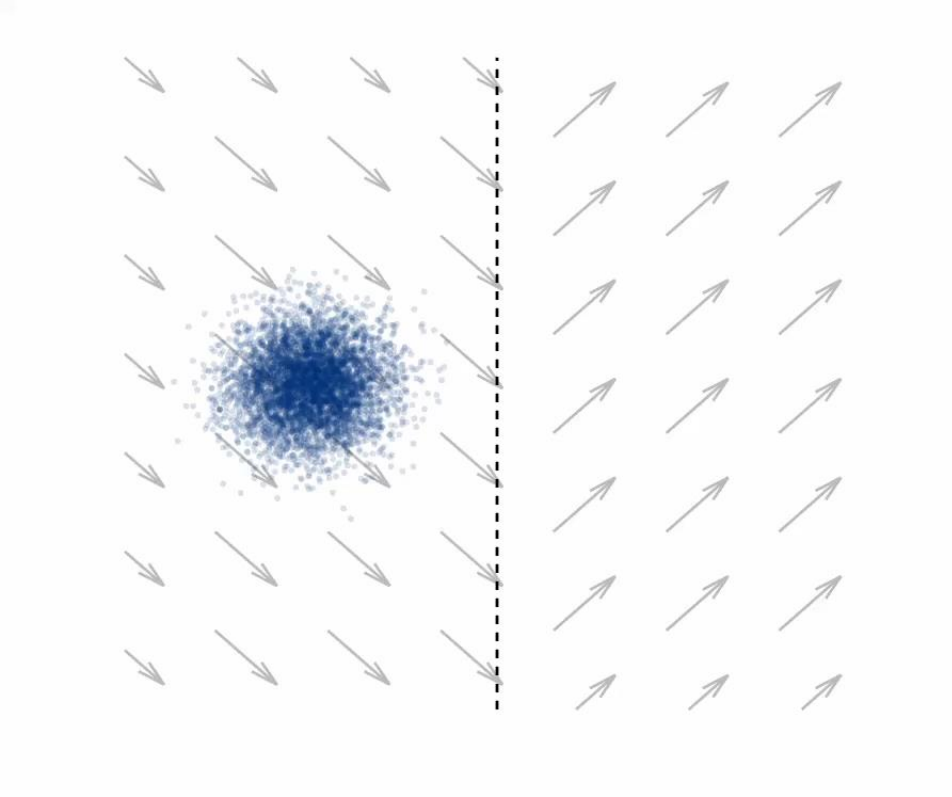
- MS or BS student

- Paper to read:

Fankhauser, Bloesch, and Hutter. “Probabilistic terrain mapping for mobile robots with uncertain localization.” *IEEE RA-L*, 2018.
https://ieeexplore.ieee.org/abstract/document/8392399

Project 2: Hybrid System Theory & Control

- How do we handle discontinuities arising from impact with the ground?
- Can we improve state estimation, control, etc with changing contacts?
- Skills: Controls, linear systems
- MS student
- Paper to read:



$$\delta x(t^+) = \Xi \delta x(t^-) + \text{h.o.t.}$$

$$\Xi := D_x R + \frac{(F_J - D_x R F_I - D_t R)\, D_x g}{D_t g + D_x g F_I}$$

Zhu, Kong, Council, and Johnson. "Hybrid Event Shaping to Stabilize Periodic Hybrid Orbits." In *ICRA,* 2022.
https://arxiv.org/pdf/2110.01123.pdf
https://www.youtube.com/watch?v=EqIjG2cCX5w

Project 3: Perception on Rough Terrain

- Perception is hard for robots on rough terrain
- True for legged, wheeled, and tracked vehicles
- Can we incorporate better dynamics models to improve vision and SLAM?

- Skills: Some ROS and computer vision experience

- Likely MS student

https://www.youtube.com/watch?v=2V9ecCBBod8

- Paper to read:

(One possible solution):
Kumar, Payne, Travers, Johnson, and Choset. "Periodic SLAM: Using Cyclic Constraints to Improve the Performance of Visual-Inertial SLAM on Legged Robots." In *ICRA*, 2022
http://www.andrew.cmu.edu/user/amj1/papers/ICRA2022_Periodic_SLAM_Paper.pdf

Project 4: Legged Controls in Clutter

- Improving capabilities of our Quad-SDK control to work in clutter or vegetation
- How should we control the legs in tight spaces or when entangled?

- Skills: Strong C/C++

- MS student

- Paper to read:

(Control architecture this project will use):
Norby et al. "Quad-SDK: Full Stack Software Framework for Agile Quadrupedal Locomotion." In *ICRA Workshop on Legged Robots*, May 2022.
http://www.andrew.cmu.edu/user/amj1/papers/Quad_SDK_ICRA_Abstract.pdf

https://www.youtube.com/watch?v=kSXKjTxKpuA
https://github.com/robomechanics/quad-sdk

Project 5: Legged Design Optimization

- How does the design of the robot's body and legs affect performance?
- What, if any, spine designs should we consider?

- This is a simulation project, at least in Year 1

- Skills: Strong C/C++

- MS or BS student

- Paper to read:

(similar type of project):
Yang, Norby, Yim, and Johnson. "Proprioception and Tail Control Enable Extreme Terrain Traversal by Quadruped Robots." In *ICRA Workshop on Legged Robots*, May 2022.
http://www.andrew.cmu.edu/user/amj1/papers/Proprioception_and_Tail_Control_ICRA_WS.pdf
https://www.youtube.com/watch?v=uH6T1ETzjhM

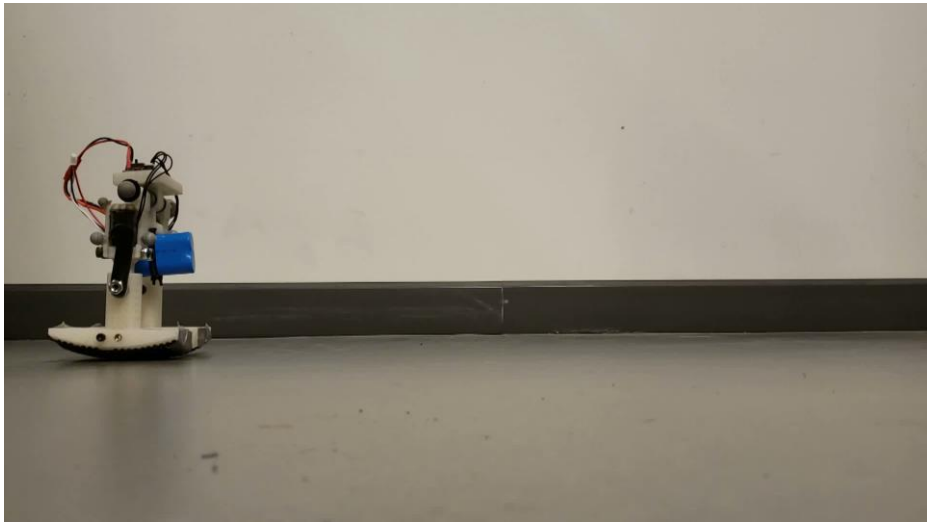
Project 6: Simple Walking Machines

- What is the simplest walking machine?
- How does walking scale to larger and smaller sizes?
- How does design and control trade off?

- Skills: Mechanical design and analysis

- Likely undergrad (CITH)

- Paper to read:



https://www.youtube.com/watch?v=kECAdJEaJlk

Islam, Carter, Yim, Kyle, Bergbreiter, and Johnson. "Scalable Minimally Actuated Leg Extension Bipedal Walker Based on 3D Passive Dynamics." In *ICRA* 2022.
http://www.andrew.cmu.edu/user/amj1/papers/ICRA2022_3D_Walker_Paper.pdf

Thank you!

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