The Robomechanics Lab

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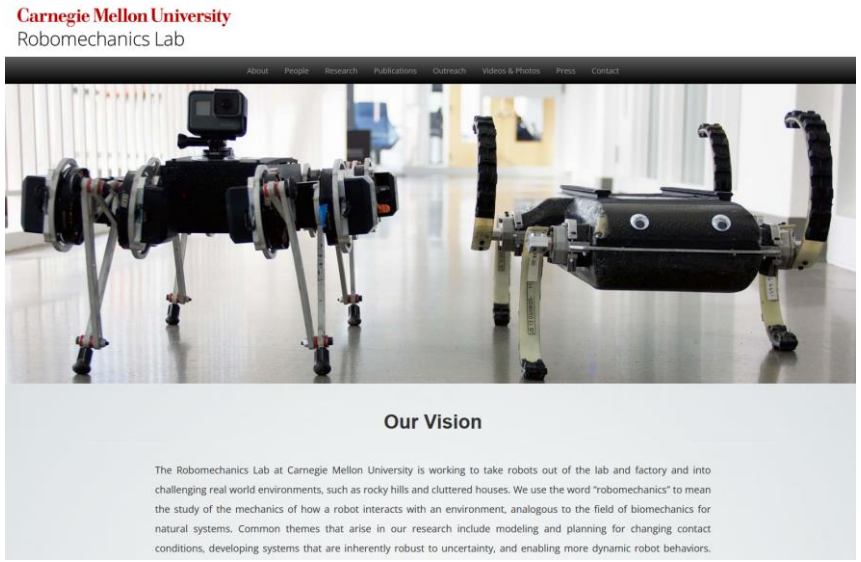
Lab Overview

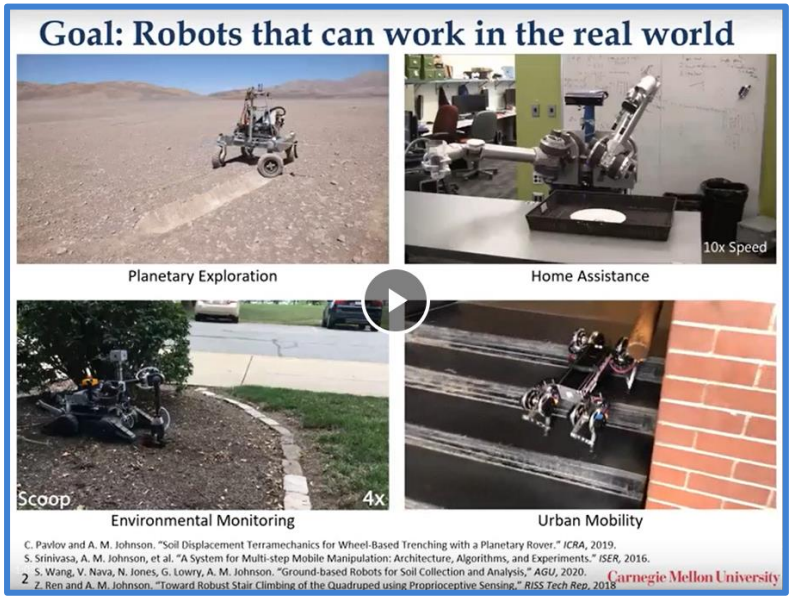
Lab Website:



With research overview, recent publications, etc
https://robomechanics.net

YouTube Channel with more talks and research videos:
https://www.youtube.com/channel/UCKD78aZAsdB9-JTwrt6Q1KA

Recent Seminar:



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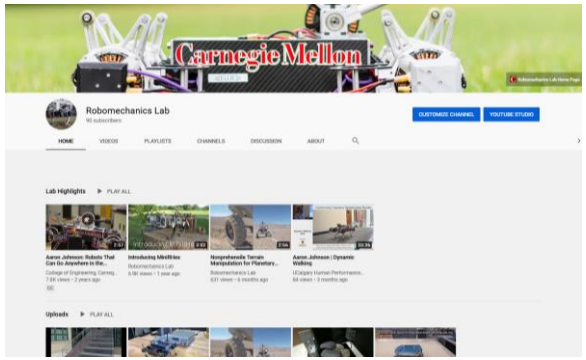


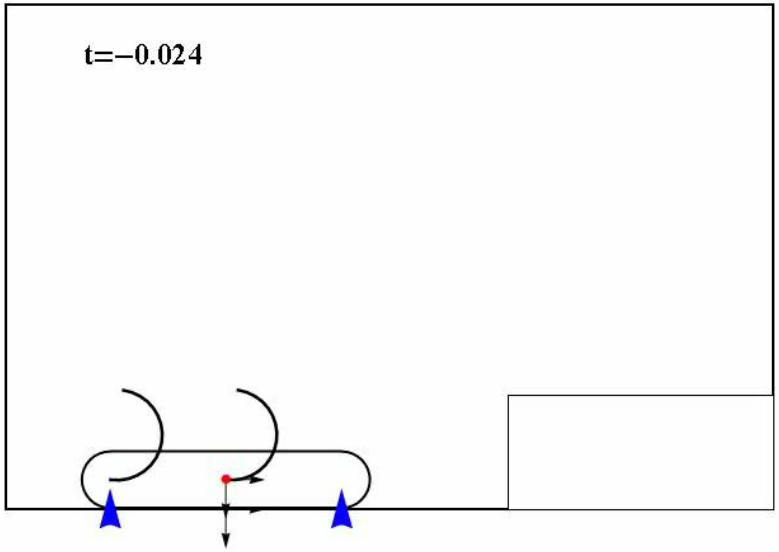
Fall 2023 Projects

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 (next slide)
- Do you fund MS-R students?
  - No. I wish I could!

Fall: 24-760 Robot Dynamics and Analysis

Format: Lecture based, weekly assignments

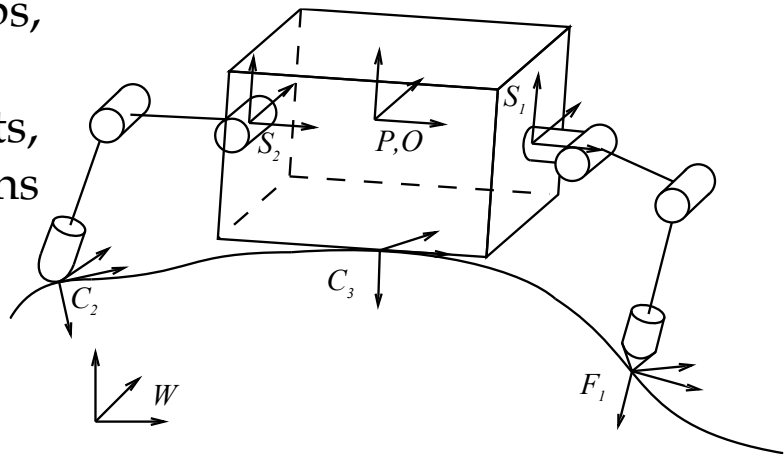


Prerequisites:

- Undergrad dynamics (should know: f=ma, inertia, torque, potential energy, etc)
- Matlab (ode45, syms, fmincon)
- Linear algebra, multivariable calculus, differential equations

Topics:

- **Math Fundamentals**: Topological spaces, maps, implicit & inverse function thm, constraints
- **Kinematics**: Frames, rotations, velocities, twists, adjoint, forward & inverse kinematics, Jacobians
- **Dynamics**: Lagrangian dynamics, constrained dynamics, (self-)manipulation dynamics
- **Contact**: Contact dynamics, impact, friction complementarity, hybrid systems
- **Simulation & Optimization**: Timestepping & hybrid simulation, shooting & direct colocation



Project 1: Environmental Monitoring Robot

- Exploration algorithms looking for contamination
- Using the wheels/tracks to homogenize the soil
- Skills: Some ROS experience
- MS or BS student
- Paper to read:

Tan, Y. T., Kunapareddy, A., & Kobilarov, M. (2018). Gaussian process adaptive sampling using the cross-entropy method for environmental sensing and monitoring. *2018 IEEE International Conference on Robotics and Automation (ICRA)*. https://doi.org/10.1109/icra.2018.8460821

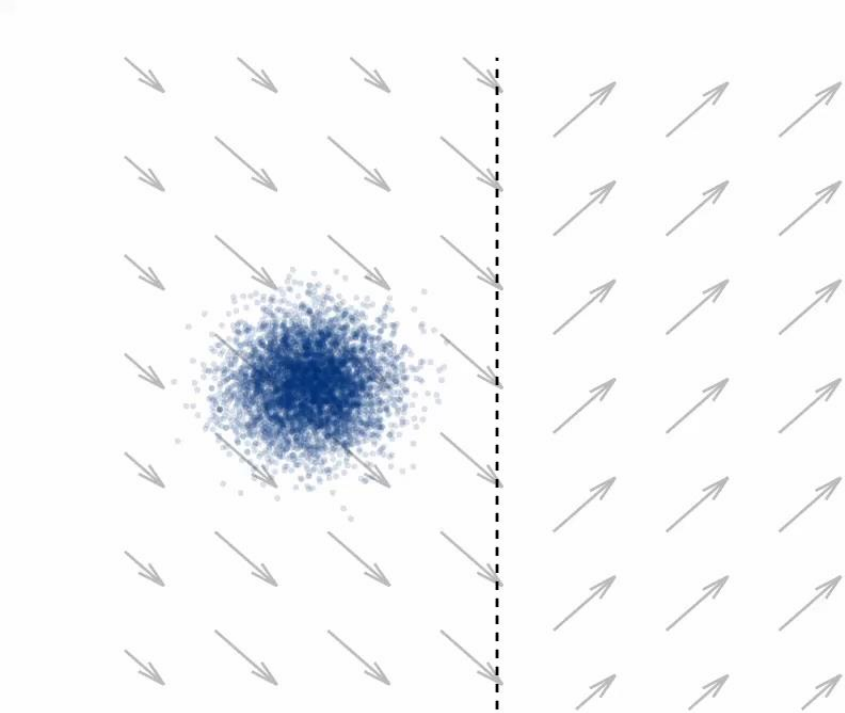
Project 2: Hybrid System Theory & Control

- 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:



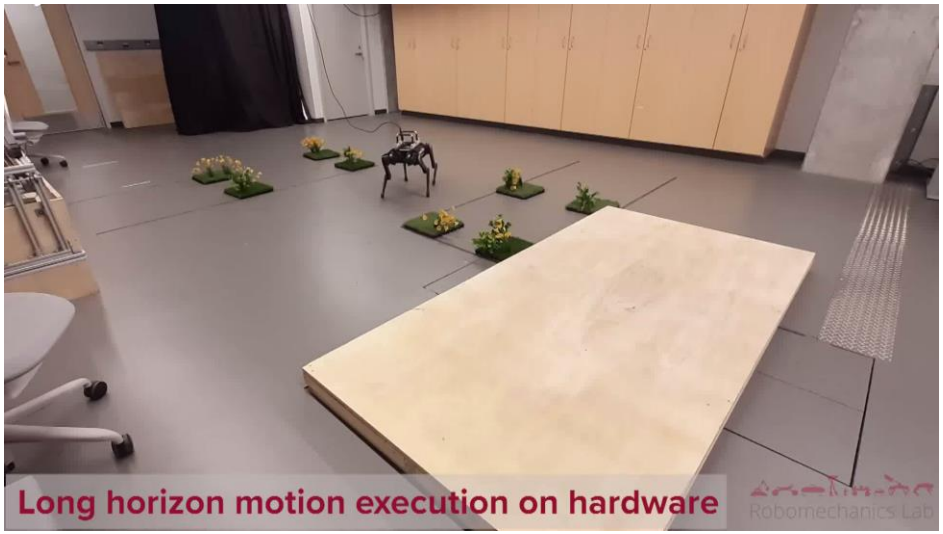
$$\delta x(t^+) = \Xi \delta x(t^-) + \text{h.o.t.}$$

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

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: Legged Controls (multiple projects)

- Improving capabilities of our Quad-SDK control stack
- Integrate advanced perception & machine learning
- Can we add & control a spine?
- Skills: Strong C/C++
- MS student
- Paper to read:



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

(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://github.com/robomechanics/quad-sdk

Project 4: Multi-agent control around humans

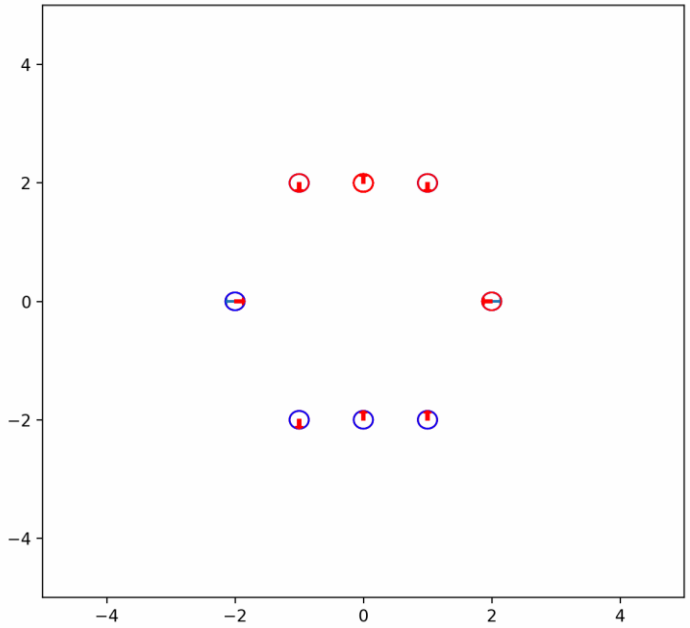
- Develop algorithms for multi-agent coordination and control
- Coordination when moving around people
- Collision detection
- Applications: warehouses, sidewalk delivery, etc

- Skills: Python and Controls/Planning

- MS student

- Paper to read:

Ardalan Tajbakhsh; Lorenz T Biegler; and Aaron M. Johnson. "Conflict-Based Model Predictive Control for Scalable Multi-Robot Motion Planning." In *arXiv:2303.01619 [cs.RO]*, 2023
https://arxiv.org/pdf/2303.01619



Project 5: Simple Walking Machines

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

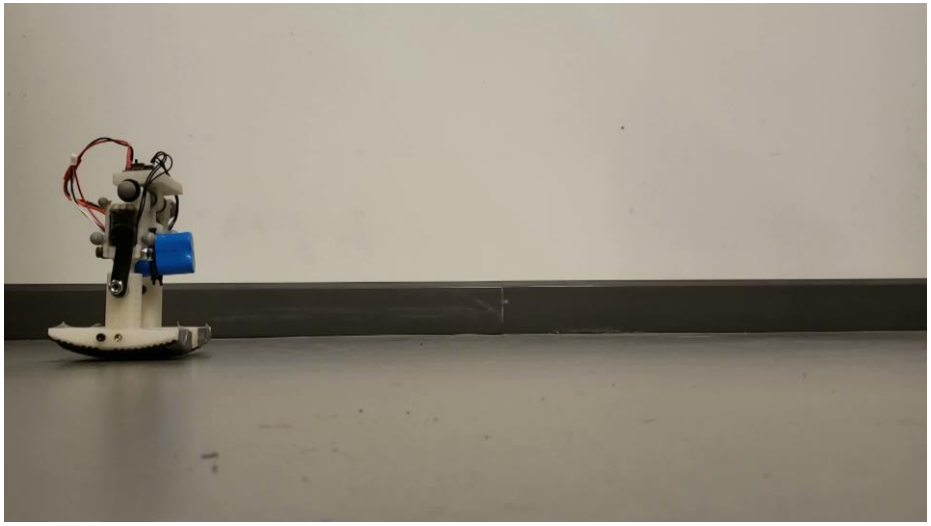
- Does a spine help a quadruped walk better?

- Skills: Mechanical design and analysis

- Likely undergrad (CITH or HURAY)

- Paper to read:

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



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

Project 6: Evaluating Human Attitudes Toward Delivery Robots

- Creating Unity-based environment to simulate human-robot interactions
- Perform interviews and surveys to evaluate factors that affect human attitudes

- Skills: Unity/game design
- BS Student
- Paper to read:

Tsoi, Nathan, et al. "Sean 2.0: Formalizing and generating social situations for robot navigation." *IEEE Robotics and Automation Letters* 7.4 (2022): 11047-11054.
https://www.nathantsoi.com/papers/SEAN_2.0_Formalizing_and_Generating_Social_Situations_for_Robot_Navigation.pdf

Thank you!

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