

Legged Robots: Practice Sessions

Week 3

Updates

- Today last ungraded assignment
- Next week: start of Mini-Project 1
 - Graded!
 - Project introduction next week
 - Teams of 3 students
- Please register teams on Moodle by next week

Team registration

MICRO-507 / General / Create student teams

Create student teams

[Group choice](#) [Settings](#) [View 0 responses](#) [More](#) ▾

Please create students teams below. If a team has already one or two members, please ask them, out of politeness, before joining the team. **Please fill lowest group numbers first and do not leave gaps in group numbers.** If you happen to join the wrong team (several people joining teams at the same time), you can normally change it again, until the team is right.

[View 0 responses](#)

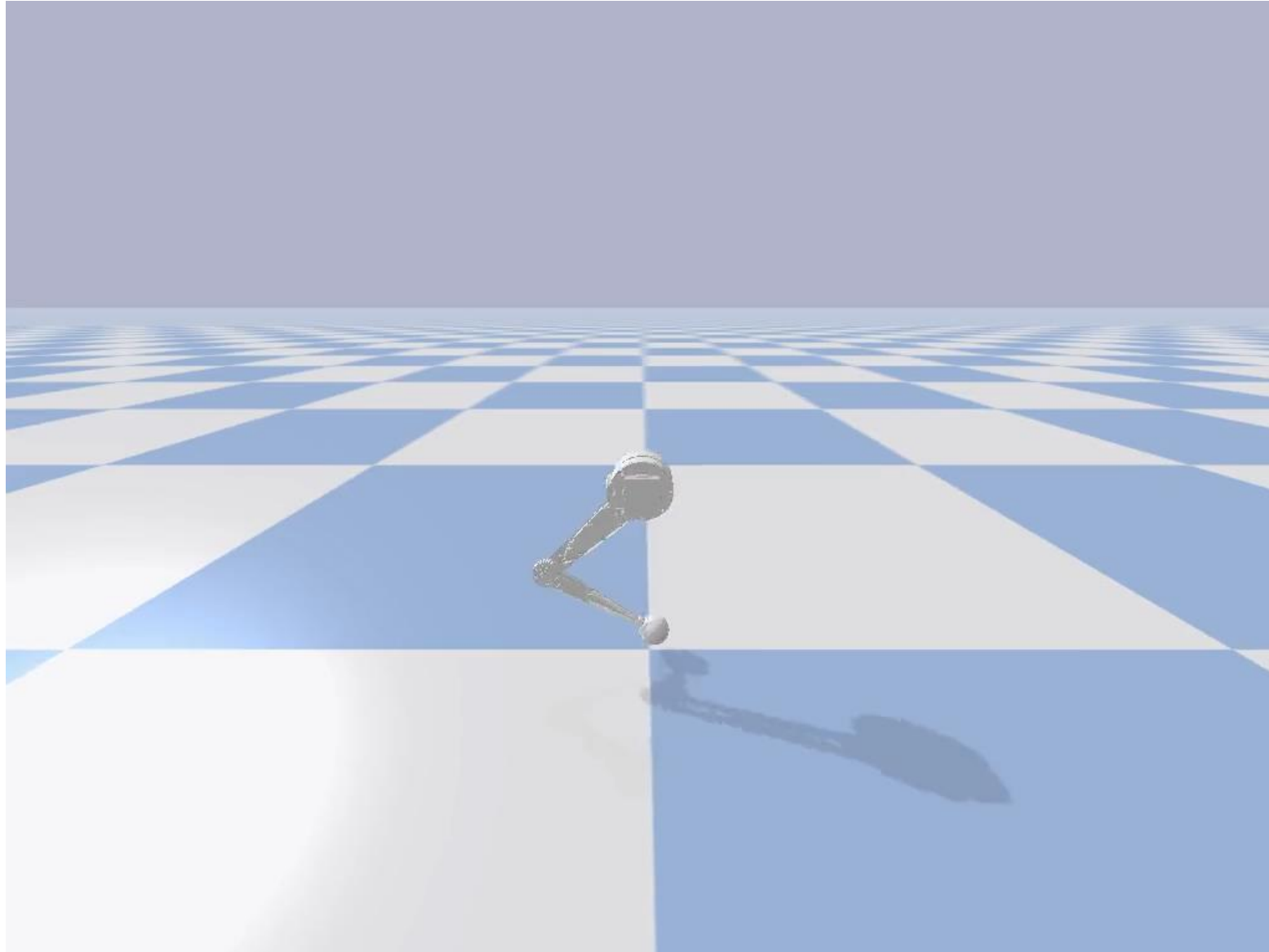
Choice	Group	Show descriptions	Members / Capacity	Group members Show Group Members
<input type="radio"/>	Group 01		0 / 3	
<input type="radio"/>	Group 02		0 / 3	
<input type="radio"/>	Group 03		0 / 3	
<input type="radio"/>	Group 04		0 / 3	
<input type="radio"/>	Group 05		0 / 3	



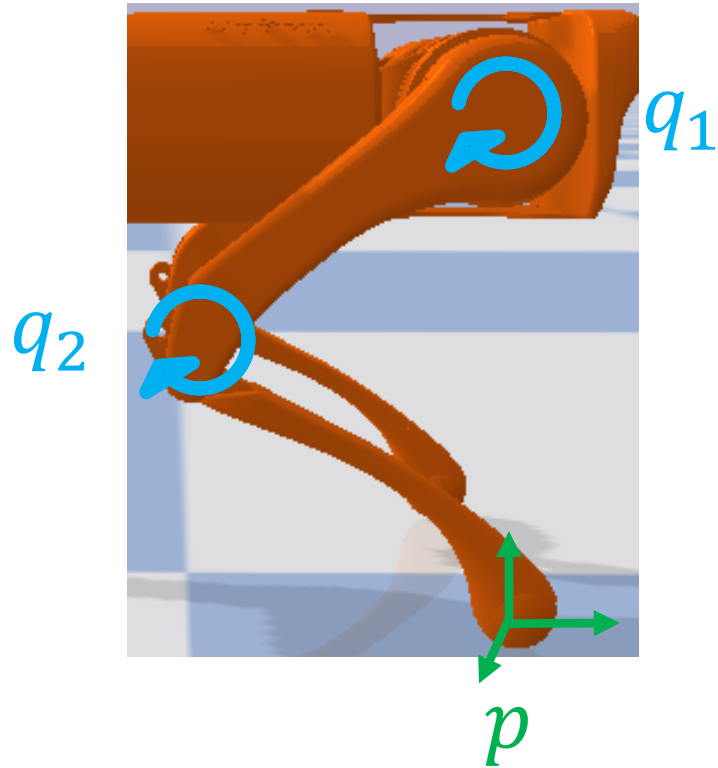
W1-3 Fundamentals

- Part 1: double pendulum kinematics and dynamics
- Part 2: Jacobian (Cartesian PD + Force Control)
- Part 3: Inverse Kinematics (compare with force control)
- **Part 4: Single-leg hopping**

Single-Leg Hopping



Joint angles \leftrightarrow Cartesian space



$$p = f(q)$$

Forward kinematics

$$q = f^{-1}(p)$$

Inverse kinematics

$$\dot{p} = v = J(q)\dot{q}$$

Foot linear velocity

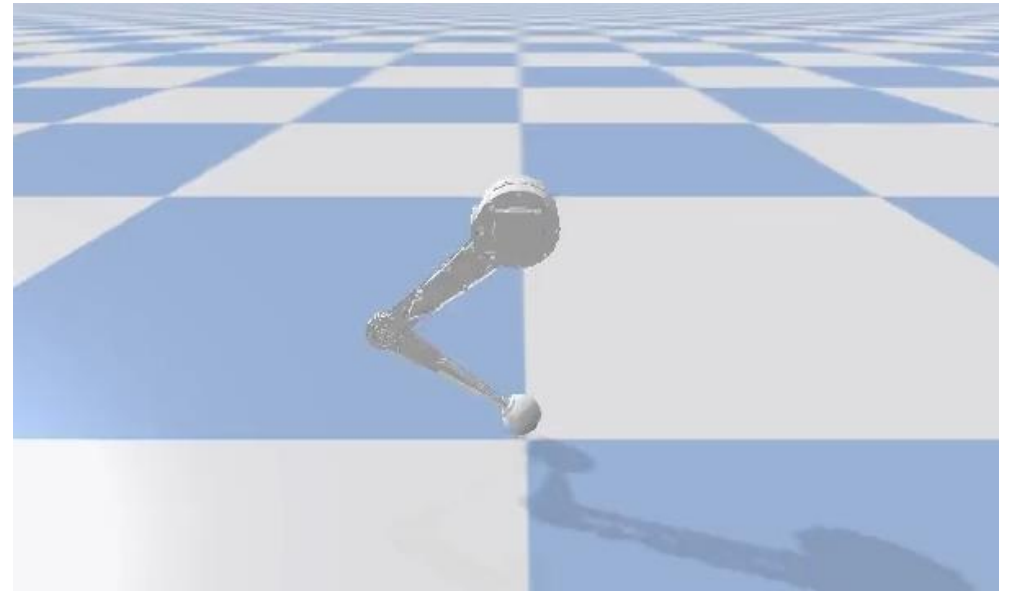
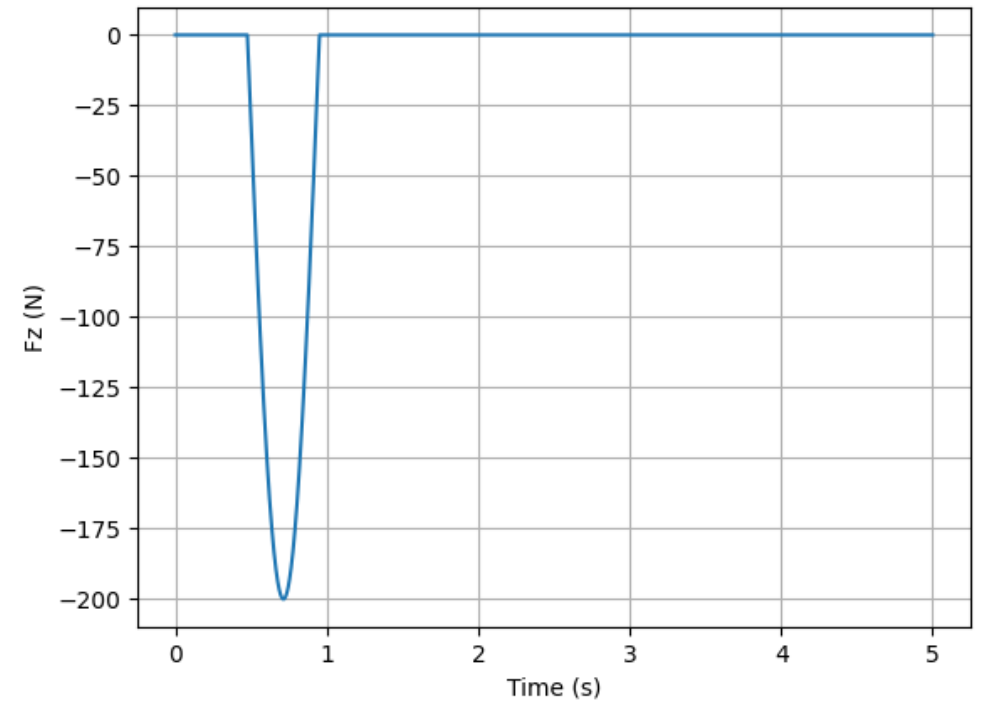
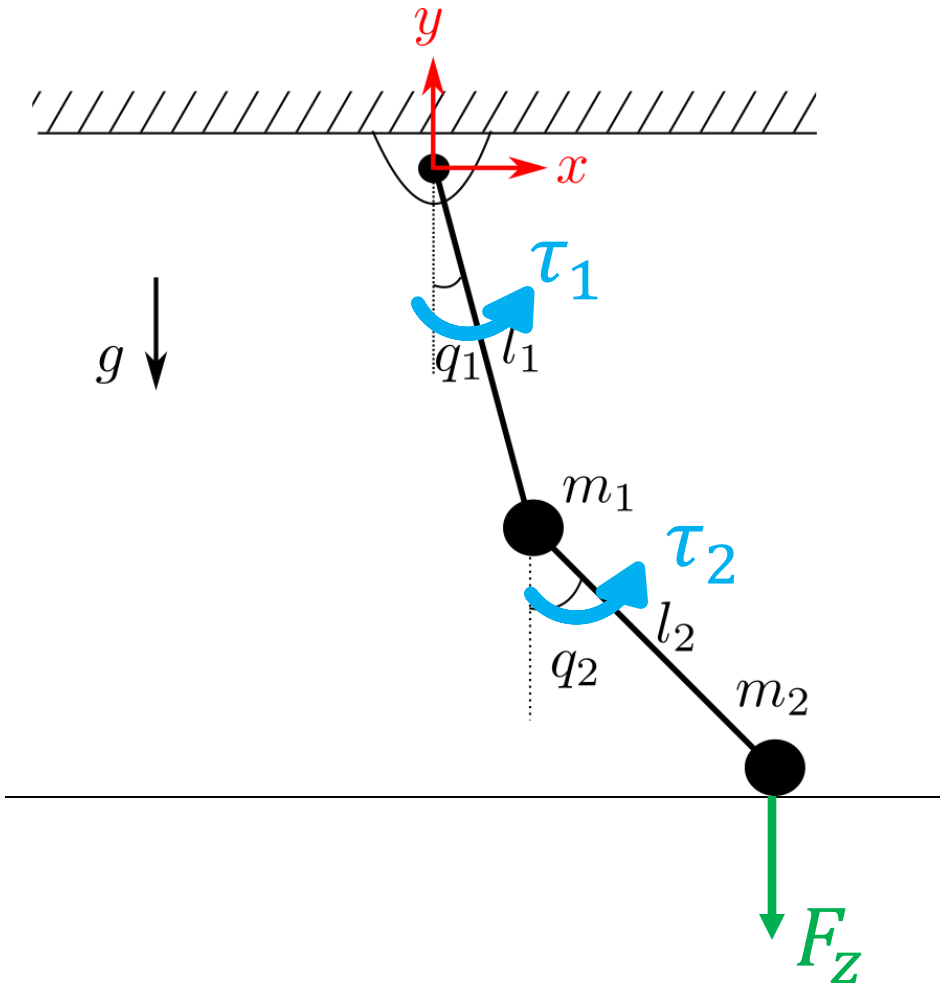
$$\tau = J^T(q)F$$

Map desired end effector force to torques

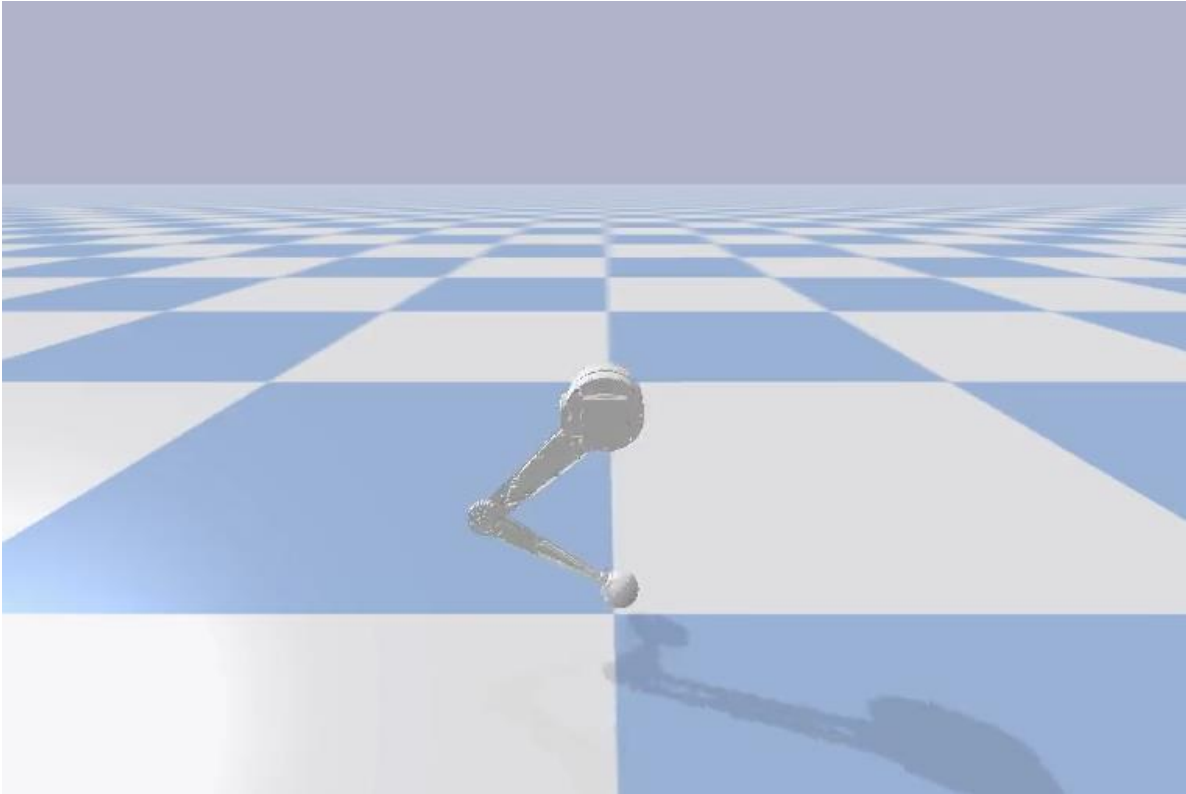
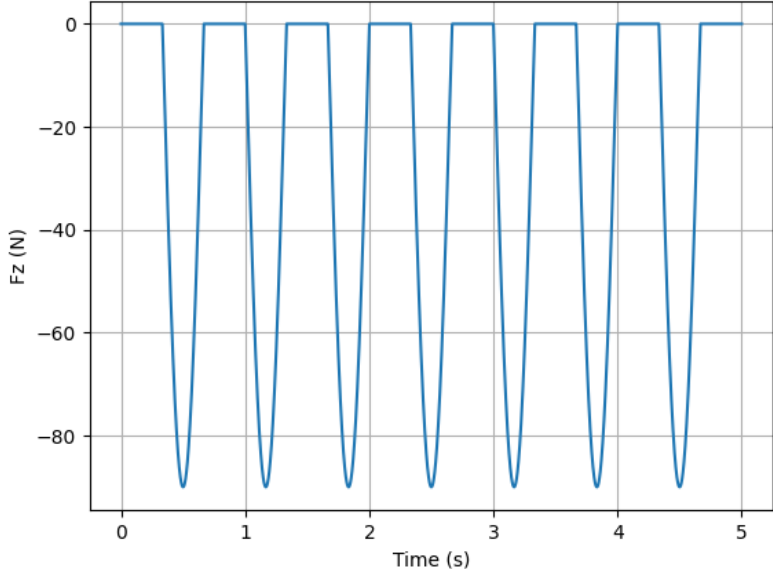
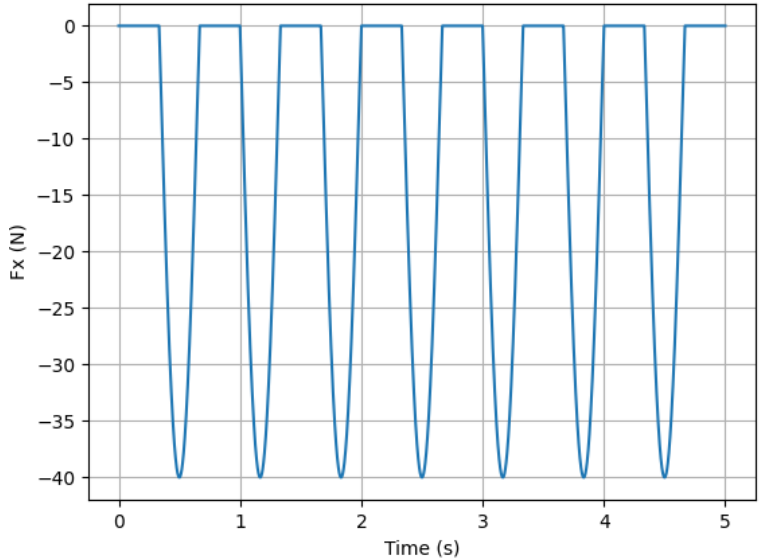
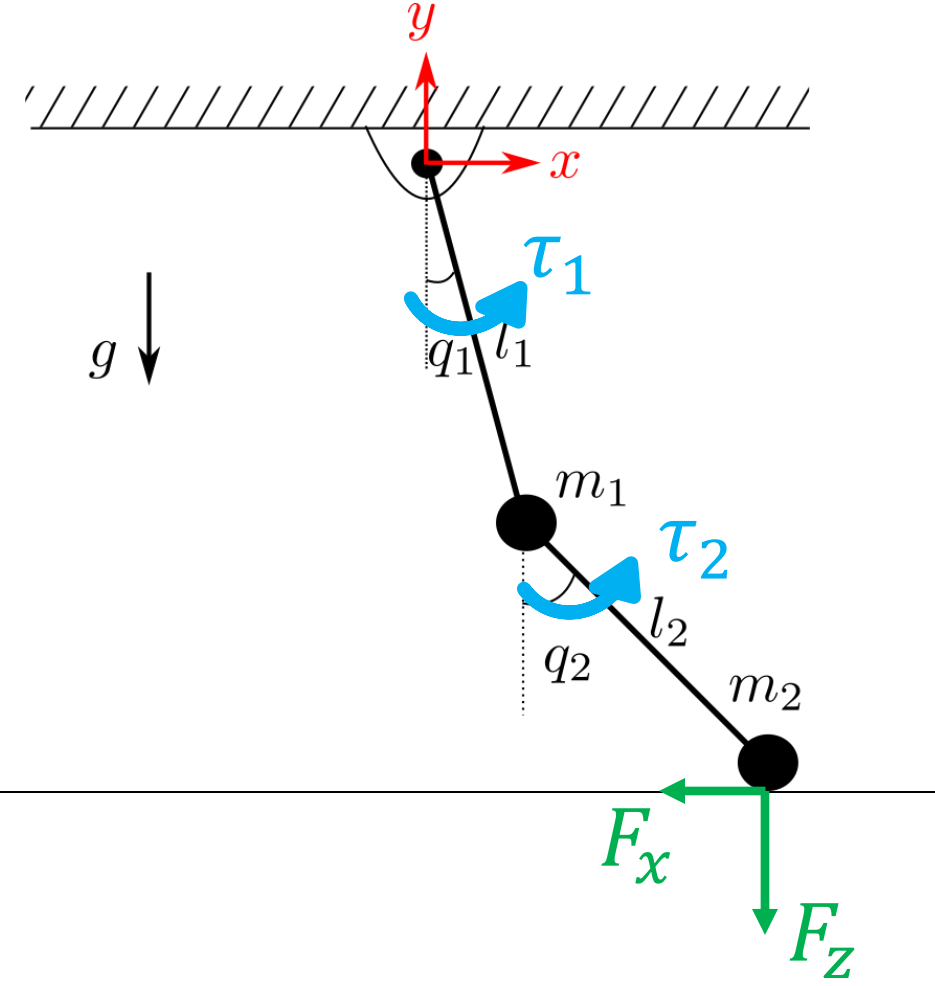
How should we design a jumping motion?

1. Joint space?
2. Task space?
3. Force?

Force Profile: Single Jump



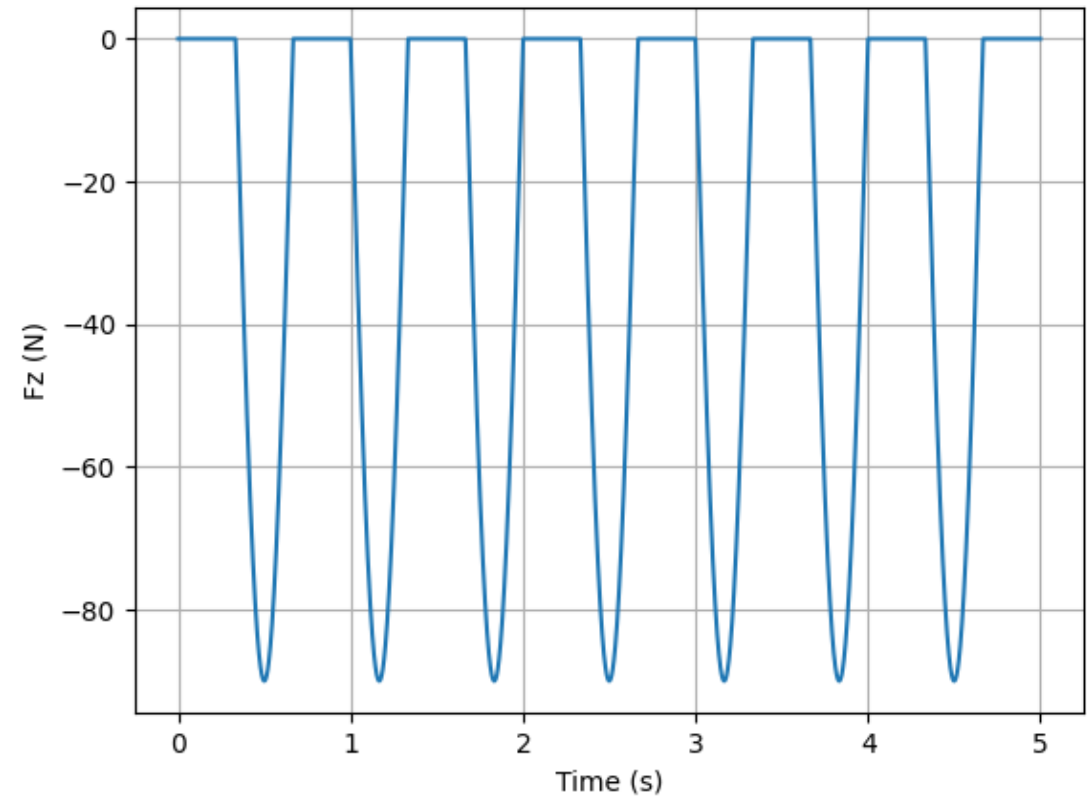
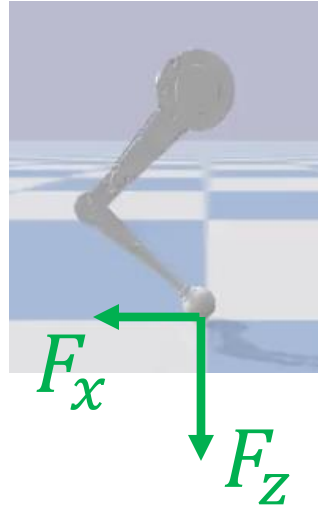
Force Profile: Continuous Jumping



How should we design the profile?

- Design decisions

- Peak force?
- Frequency?
- Initial/nominal position?
- Joint/Cartesian gains?
 - (In swing/stance)?



$$\tau_{joint} = K_{p,joint}(q_d - q) + K_{d,joint}(\dot{q}_d - \dot{q}) \quad \text{Joint PD}$$

$$\tau_{Cartesian} = J^T(q) [K_{p,Cartesian}(p_d - p) + K_{d,Cartesian}(v_d - v)] \quad \text{Cartesian PD}$$

$$\tau_{final} = \tau_{joint} + \tau_{Cartesian} + J^T(q)F \quad \text{Total applied torque}$$

Optimization

- Choose parameters you would like to optimize

$$\mathbf{x} = [f, F_{z_{\text{peak}}}, \dots]$$

- Formulate an unconstrained optimization with objective (– *max_height* ?)

$$\underset{x}{\text{minimize}} f(x)$$

- Set upper/lower bounds on variables, and give an initial condition
- We provide an interface to *pymoo* and CMA-ES

<https://pymoo.org/index.html>

<https://pymoo.org/algorithms/soo/cmaes.html>

Assignment

- Start from <https://gitlab.epfl.ch/lgevers/lr-practicals>
- Instructions are on Moodle
- This week: finish remaining practicals (including part 4)
- The assignment for weeks 1-3 are not graded