MEAM 517: Control and Optimization with Applications in Robotics (Preliminary Syllabus)

Fall 2018

Lectures: MW 9-10:30am in TBD

Webpage

Canvas: https://canvas.upenn.edu/courses/TBD
Discussion forum via Piazza.

Staff

Instructor:	Michael Posa posa@seas.upenn.edu Towne 276	**Teaching Assistant:**	TBD tbd@upenn.edu
Office Hours:	TBD		

Reading

There is no formal textbook for this course. The Canvas site will reference a number of online texts and research papers relevant to each week's material. At least once over the course of the semester, each student must choose one reading and post a brief (roughly $\frac{1}{2}$ to 1 page) summary to the Piazza discussion forums. A separate thread on Piazza will track which students have "claimed" which readings, to prevent any overlap.

Software

This course will regularly make use of MATLAB and Python for both in-class examples and homework. For SEAS students, MATLAB is available from CETS. See https://www.seas.upenn.edu/cets/software/matlab/ for more information. With prior approval by the instructor, students may choose to prepare their assignments using an alternate programming language of their choice.

Course Description

This course covers a variety of advanced topics in model-based nonlinear control, primarily focused on computational techniques and dynamic robotic applications. Students will learn both the theoretical basics of nonlinear and optimal control along with optimization-based algorithmic methods. Topics include optimal control, dynamic programming, trajectory optimization, canonical underactuated systems, control of limit cycles, stability analysis, walking and running robot, nonsmooth mechanics, and model predictive control. As the course will cover state of the art techniques, we will review relevant research papers.

Prerequisites

Functional skills in MATLAB, Python, or another programming language (and appropriate mathematical toolboxes) and basic knowledge of the following subjects will be assumed:

- Controls or Robotics (e.g. MEAM 513/ESE 505, ESE 500, MEAM 520, or equivalent)
- Linear algebra (MATH 312 or equivalent)
- Dynamics (MEAM 211 or equivalent)

While these courses are not strictly required (and only partial knowledge will be needed), students without any prior knowledge will need to catch up at the beginning of the semester. Students may find experience in more advanced classes covering dynamics, linear systems, nonlinear control, robotics, and optimization to be complementary.

Grading Policy

Homework	30%
Midterm	30%
Final Project	35%
Participation	5%

Homework

Please read the following list carefully.

- Homework will be due every week or so, typically at the **beginning of class on Wednesdays**.
- All students will be permitted **ONE** assignment to be submitted up to one week late.
- Late assignments, starting with those submitted after the start of lecture, will be deducted **10% credit per day**, and should be submitted either in lecture or under the door of the instructor's office. **Late assignments should be clearly marked with the time of submission**.
- Assignments are intended to **reinforce AND expand** upon material from lecture.
- At the end of the semester, the **lowest** grade on one homework assignment will be not count toward your final grade.

Exam

There will be one midterm exam for this course and no final exam. Students may bring up to **TWO** single-sided pages of handwritten notes. Make-ups will be given only under extreme circumstances, at the discretion of the instructor. Any conflicts with the exam dates should be brought to the instructor as soon as possible to increase the likelihood of an alternate date being offered.

Important date(s): Midterm on TBD (in class)

Project

At the end of the semester, students will present the results of a final project in the form of a short presentation and a report. These projects are intended to take the material taught in the course in a new and insightful direction of your choosing, for instance by incorporating the course into your research. Specific details on the project will be available mid-semester.

Wellness and Counseling

You are not alone. Most if not all students struggle at some point throughout the year, but there are many helpful resources available on campus. If you or someone you know is going through a tough time, we strongly encourage you to seek support. **Counseling and Psychological Services (CAPS)** is the counseling center for the University of Pennsylvania. CAPS offers free and confidential services to all Penn undergraduate, graduate, and professional students. For more information, visit http://www.vpul.upenn.edu/caps/. Consider also reaching out to a friend, family or faculty member.

Academic integrity

From the Pennbook:

> Since the University is an academic community, its fundamental purpose is the pursuit of knowledge. Essential to the success of this educational mission is a commitment to the principles of academic integrity. Every member of the University community is responsible for upholding the highest standards of honesty at all times. Students, as members of the community, are also responsible for adhering to the principles and spirit of the following Code of Academic Integrity.

Consequences for academic dishonesty range from receiving a 0 on a homework or exam to disciplinary action. Ignorance of the Code of Academic Integrity is not an acceptable defense. For example, using outside solutions to homework problems is not acceptable.

- Code of Academic Integrity:
  https://provost.upenn.edu/policies/pennbook/2013/02/13/code-of-academic-integrity
- SEASs Student Code of Ethics:
  http://www.seas.upenn.edu/undergraduate/handbook/student-ethics.php

Sexual Harassment and related policies

All forms of sexual violence, relationship violence and stalking and attempts to commit such acts are considered to be serious misconduct and may result in disciplinary action up to and including expulsion or termination of employment. In addition, such acts may violate federal, state and local laws and perpetrators of such acts may be subject to criminal prosecution. For more information, please refer to Penns Sexual Harassment Policy, http://provost.upenn.edu/policies/pennbook/2013/02/15/sexual-harassment-policy, as well as the other related policies available at this link.

Students with Disabilities and Learning Differences

Students with disabilities are encouraged to contact Weingarten Learning Resource Centers Office for Student Disabilities Services for information and assistance with the process of accessing reasonable accommodations. For more information, visit http://www.vpul.upenn.edu/lrc/sds/, or email lrcmail@pobox.upenn.edu.

MEAM 517: Course Outline*

Week of	Topics
Aug. 27 (Wed. only)	Introduction
Sept. 3 (Wed. only)	Nonlinear dynamics and stability
Sept. 10	Optimal control, the HJB equation, and and dynamic programming
Sept. 17	Linearization and LQR
Sept. 24	Underactuated systems Partial feedback linearization and energy shaping
Oct. 1	Introduction to optimization: convexity, LP, QP, SQP Trajectory optimization
Oct. 8	More trajectory optimization: direct and indirect methods, collocation, iLQR, DDP, pseudospectral method
Oct. 15	Periodic motion and limit cycles Poincaré maps, transverse coordinates, and zero dynamics
Oct. 22	Lyapunov stability and passivity, Regions of attraction.
Oct. 29	Sums-of-squares optimization, Introduction to MPC
Nov. 5	Simple models for legged locomotion: rimless wheel, inverted pendulum, SLIP, and LIP
Nov. 12	Hybrid systems and nonsmooth mechanics
Nov. 19 (Mon. only)	Manipulation
Nov. 26	Nonlinear system identification
Dec. 3	Catchup and Project presentations
Dec. 10 (Mon. only)	Project presentations

*Outline is a tentative schedule of the semester, and will be modified depending on our progress. The midterm date is fixed.