Introduction to Robotics (Fall 2022)

MAE 345 / ECE 345 / COS 346 / MAE 549

Assignment 1

Due Wed, Sept. 21st by midnight

Instructions: Collaboration on the assignment is permitted (encouraged). But, you must turn in your own solutions for *all* portions of this assignment (theory and coding portions). Please submit your work via Gradescope (instructions are at the end of this document).

Part I: Theory

Problem 1 (MAE 345). MAE 345 students only (MAE 549 students: please skip this and do the problem marked "Problem 1 (MAE 549)").

The following equation of motion (EOM) describes the dynamics of a pendulum with a control input in the form of a torque u:

$$\ddot{\theta} = -\frac{g}{l}\sin\theta + u. \tag{1}$$

(a) (10 pts) How many states does this system have (i.e., what is the dimension of the state vector)? How many control inputs? Convert the second-order differential equation above to a system of first-order differential equations.

(b) (20 pts) Linearize the dynamics of the pendulum about the reference point given by $\theta_0 = 0, \dot{\theta}_0 = 0, u_0 = 0$. (You should write out the A and B matrices corresponding to the linearized dynamics).

Problem 1 (MAE 549). MAE 549 students only (MAE 345 students are welcome to attempt this, but we won't grade it).

The following equations describe the dynamics of a cart-pole system with control input in the form of a force u (acting on the cart):

$$2\ddot{x} + \ddot{\theta}\cos(\theta) - \dot{\theta}^2\sin(\theta) = u \tag{2}$$

$$\ddot{x}\cos(\theta) + \ddot{\theta} - \sin(\theta) = 0. \tag{3}$$

(a) (10 pts) How many states does this system have (i.e., what is the dimension of the state vector)? How many control inputs? Convert the second-order differential equations above to a system of first-order differential equations.

(b) (20 pts) Linearize the dynamics of the cart-pole about the reference point given by $x_0 = 0, \dot{x}_0 = 0, \theta_0 = 0, \dot{\theta}_0 = 0, u_0 = 0$. (You should write out the A and B matrices corresponding to the linearized dynamics).

Part II: Coding (both MAE 345 and 549 students should complete all portions of this)

Please follow the link to our GitHub page below and follow the instructions in the "Install Instructions" and "Working on Assignments" sections. Please complete the problems in the "Lab1.ipynb" notebook. When you have completed this, please follow the submission instructions at the end of the jupyter notebook.

https://github.com/Princeton-Introduction-to-Robotics/F2022

Part III: Reading (MAE 549)

(0 pts) Read the paper "Creation Myths: The Beginnings of Robotics Research", by Matt Mason (a pioneer in robotic manipulation):
https://ieeexplore.ieee.org/document/6203452

You should be able to access the article by signing in to IEEE Xplore through your Princeton credentials.

(0 pts) Read "The Puzzle of the Missing Robots", by Suzanne Berger and Benjamin Armstrong:
https://mit-serc.pubpub.org/pub/puzzle-of-missing-robots/release/1

[Note: This portion of the assignment does not have any points (and there is nothing to submit). But, I highly recommend reading these excellent articles!]

Submission Instructions

Part I: Theory Submission You can submit your written work for Part I (Theory) in Gradescope (accessed via Canvas) to "HW1: Theory". You will have the option to submit each problem as individual images or the entire assignment as one PDF. If submitting as one PDF, Gradescope will ask you to identify where problems are located. For more information, watch "For students: submitting PDF homework" from Gradescope's Get Started page https://www.gradescope.com/get_started.

Part II: Coding Submission Please submit your completed Jupyter Notebook (Lab1.ipynb file) for Part II (Coding) in Gradescope to "HW1: Coding".