Course Project Part 1: Controller Design in simulation

Due: April 4 2025, Friday

Background: In this class, we are learning about different nonlinear controllers. This course project will allow you to implement and test some of these controllers on physical hardware. You will first design candidate controllers for the ball and beam system [1] in MATLAB. In Part 2 of this project, later in the semester, you will test, and debug, these controllers on hardware to evaluate their performance.

Directions

- Form groups of 3-4 people to work together on this project
- The code and instructions for developing your proposed controllers can be downloaded from here. Please fork or import this repo and work on it as you will be asked to upload a GitHub repo at the end. To easily import this repo see this guide here. Please make your repositories private until submission.
- The above repo contains a file, *EE_222_Course_Project.pdf* (from an older version of this course), that has detailed information about the model for the ball and beam system as well as instructions on how to implement and test your proposed controller in MATLAB. Don't use the older repo link given in that document instead use the repo above which is updated.
- The following are required deliverables

    1. Two different proposed controllers implemented and tested in simulation
    2. An observer implemented for performing state-estimation
    3. A brief report (3-4 pages) describing the proposed controllers and observer and some commentary on their relative performance in simulation. Please cite any papers/work that was used in controller/observer design.
    4. Each group member must submit a link to the shared modified GitHub repository which contains:
        - The final report in the root directory titled *EE222_project_report_part1.pdf*. (formatted in LaTeX)
        - The MATLAB files for the developed controllers and observer.
        - A README file summarizing the simulation results and including a screen recording of the controller animation.

[1] `https://www.quanser.com/products/ball-and-beam/`

Additional Remarks

- Please do not implement an MPC controller. These may not work on hardware because of software interface limitations.
- As is noted in *EE_222_Course_Project.pdf*, the model you will use in simulation will almost have modeling errors and forces that are not modeled/consider (e.g. friction). There are also other factors that will impact the performance of your controller, e.g. measurement noise. These factors will become more apparent as we test your proposed controllers but should also be considered in controller/observer design.
- The system may not have a well defined relative degree for parts of the state-space. Therefore, some adjustments may be required to use feedback linearization on this system [2]
- **F.A.Q. and Feedback:** Review the FAQ and feedback documents in the repository before starting the project.
- **Creativity Encouraged:** Creative and well-justified solutions will be rewarded.

Grading Rubric

- **20 points:** Observer design with a thorough explanation
- **20 points each:** Design and explanation of Controller 1 and Controller 2, including implemented safety measures
- **10 points:** Simulation results for sine and square wave inputs, along with a performance score table
- **10 points:** Analysis and discussion of simulation outcomes
- **10 points:** Well-structured, readable code and a clean, organized GitHub repository
- **5 points:** Simulation demonstration video included in the GitHub repository
- **5 points:** Testing of the controller in Simulink

[2] Hauser, John, Shankar Sastry, and Petar Kokotovic. "Nonlinear control via approximate input-output linearization: The ball and beam example." IEEE transactions on automatic control 37.3 (1992): 392-398.