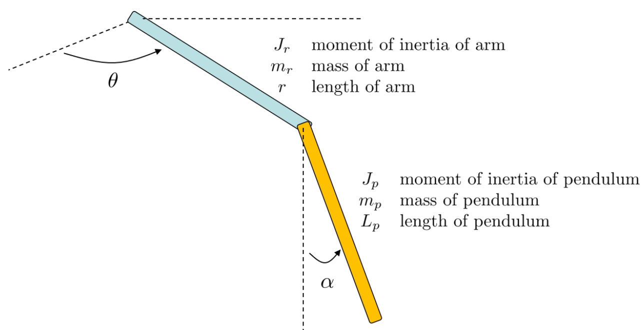
MECH468 Modern Control Engineering
MECH509 Controls

Homework 5. Due: April 6 (Tuesday), 11:59 pm, 2021.

LQR Balancing Control of Inverted Pendulum (IP)

Consider a rotary pendulum shown below. This system has been taken from https://www.quanser.com/products/qube-servo-2/. The control objective is to balance the inverted-pendulum (IP) at the upright position. To do this homework, you need Quanser software "QLabs Virtual Experiments." Please see the file MECH468509_QLabs.pdf on Canvas.



Matlab files

You will get the following Matlab files on Canvas.

- HW5_main.m: Main file for this homework
- HW4_para.m: System parameters
- HW4_ABCD.m: Linearized model around pendulum upright position
- Simulink files
  - HW5_LQR.slx: Discrete-time LQR control (Lec 27)
  - HW5_LQRServo.slx: Discrete-time LQR servo control (Lec 27)
  - HW5_LQG.slx: Discrete-time LQR control with Kalman filter (Lec 30)
  - HW5_LQGServo.slx: Discrete-time LQR servo control with Kalman filter (Lec 30)

Control tasks

There are four tasks, in which you need to find weighting matrices Q and R for discrete-time LQR control and covariance matrices Q_n and R_n for Kalman filters which lead to successful inverted-pendulum balancing control.

1. LQR controller design (balancing IP at $\theta = 0$)
2. LQR servo controller design (balancing IP and moving arm between -30 and 30 degree)
3. LQR controller design with Kalman filter (LQG)
4. LQR servo controller design with Kalman filter (LQG with an integrator)

Procedure

The basic procedure of running the QLab pendulum system is as follows.

1. Open 'Quanser Interactive Labs', 'QUBE - Pendulum', 'Pendulum Workspace'.
2. In 'HW5_main.m', specify matrices (Q, R, Q_n, R_n). Run 'HW5_main.m'.
3. Open and run a Simulink file (for example 'HW5_LQR.slx' for LQR control).
4. In 'Pendulum Workspace', if the upper-edge of the pendulum base becomes green, the system is ready. Click 'Lift pendulum' from the top-right menu.
5. Once you see the control result in the animation, stop the Simulink.

Report requirements

For each of the tasks above, only the followings are required in your report.

- Matrices (Q, R, Q_n, R_n) that you selected. We (TA) will check if your matrices give your plots.
- Time responses of
  - pendulum angle α (Note that 0 degree corresponds to the upright position, as opposed to the figure above.)
  - arm angle θ
  - motor input voltage

——— (Have fun!) ———