Lab 4 Report Format - ECE410

Cover page:

- title and course number
- names and student numbers
- lab date
- submission date

Note:

- Both handwritten and typed reports are acceptable.
- Please don't use a lab book for the report.
- The lab report is due 2 weeks after your lab session.

1 Introduction

- Introduction and a brief explanation of the inverted pendulum on a cart system.

2 Preparation

- Nonlinear state-space system model

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, V) = ? \qquad \mathbf{y} = \mathbf{g}(\mathbf{x}, V) = ?$$

- What is or what are the equilibrium point(s)?
- Linearized system model

$$(\mathbf{A}, \mathbf{B}, \mathbf{C}, \mathbf{D}) = (\text{all matrices in terms of operating points } \left(y_{eq}, \theta_{eq}, \dot{y}_{eq}, \dot{\theta}_{eq}\right))$$

- State-feedback controller gain and observer gain obtained from pole placement:

$$\mathbf{K} = ? \qquad \mathbf{L} = ?$$

- Simulation plots for pole placement controller + observer, $(y_o, \theta_o, \dot{y}_o, \dot{\theta}_o) = (0, 10^\circ \times \frac{\pi}{180^\circ}, 0, 0)$:
  1. Plot on the same graph: $y(t)$, $\hat{y}(t)$ and $y_d(t)$.
  2. Plot on the same graph: $\theta(t)$ and $\hat{\theta}(t)$.
  3. Plot on the same graph: $\dot{y}(t)$ and $\dot{\hat{y}}(t)$.
  4. Plot on the same graph: $\dot{\theta}(t)$ and $\dot{\hat{\theta}}(t)$.
- State-feedback controller gain from optimal controller design technique:

$$\mathbf{K} = ?$$

- Simulation plots for optimal controller + observer, $(y_o, \theta_o, \dot{y}_o, \dot{\theta}_o) = (0, 10^\circ \times \frac{\pi}{180^\circ}, 0, 0)$:
  1. Plot on the same graph: $y(t)$, $\hat{y}(t)$ and $y_d(t)$.
  2. Plot on the same graph: $\theta(t)$ and $\hat{\theta}(t)$.
- MATLAB scripts

3 Experiment

3.1 Tuning Optimal Controller for better Tracking

(a) Plot the response of applying the optimal controller design in the prelab on the actual physical system:

1. Plot on the same graph: $y(t)$ (simulated), $y(t)$ (actual), and $y_d(t)$.
2. Plot on the same graph: $\theta(t)$ (simulated), $\theta(t)$ (actual).
3. Plot on the same graph: $\dot{y}(t)$ (actual) and $\dot{\hat{y}}(t)$ (actual).
4. Plot on the same graph: $\dot{\theta}(t)$ (actual) and $\dot{\hat{\theta}}(t)$ (actual).

Briefly discuss how well the cart tracks the square wave.

Briefly discuss how well the observer estimates the states.

(b) How does varying the values of q_1, q_2, and r affect the response of the system?

(c) Final values of q_1, q_2, and r that gives a better response than the prelab controller:

$$q_1 = ? \quad q_2 = ? \quad r = ?$$

Plot the better response:

1. Plot on the same graph: $y(t)$ (actual), and $y_d(t)$.
2. Plot on the same graph: $\theta(t)$ (actual).

3.2 Testing the Robustness of the system

(c) Plot how the pendulum responds to the *tapping*:

1. Plot on the same graph: $y(t)$ (actual), and $\theta(t)$ (actual).

Briefly discuss how the pendulum reacts to physical disturbances.

(d) How does varying the values of q_1, q_2, and r affect the robustness of the system?

(e) Final values of q_1, q_2, and r that makes the system more robust than the prelab controller:

$$q_1 = ? \quad q_2 = ? \quad r = ?$$

Plot:

1. Plot on the same graph: $y(t)$ (actual), and $\theta(t)$ (actual).