Lab 6 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.
- Submit one report per lab group.
- Please don't use a lab book for the report.
- The lab report is due 7 days 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

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

- What is or what are the equilibrium point(s)?
- Linearized system model
$$(\mathbf{A}, \mathbf{B}, \mathbf{C}, \mathbf{D}) = ?$$
- State-feedback controller gain and observer gain obtained from pole placement:

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

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

3 Experiment

I. Stabilization and State Regulation

Record all experimental observations on getting the stabilizing controller to balance the inverted pendulum.

Testing the Robustness of the system

(a) 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.

(b) How does varying the control poles affect the robustness of the system?

(c) Final choice of controller poles that makes the system more robust than the prelab controller:

$$\text{Final choice of controller poles} = ?$$

Plot the better response:

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

II. Stabilization and Output Tracking

Record all experimental observations on the performance of the stabilization and output tracking controller designed in your prelab.

Tuning the Controller for better Tracking

(a) Plot the response of applying the 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: $\dot{y}(t)$ (actual) and $\dot{\hat{y}}(t)$ (actual).
3. Plot on the same graph: $\theta(t)$ (simulated), $\theta(t)$ (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 control poles affect the response of the system?

(c) Final choice of the control poles that gives a better response than the prelab controller:

$$\text{Control poles} = ?$$

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).

Comment on any experimental difficulties you may have encountered throughout the experiment. Discuss whether or not your control designs were successful in achieving the control objectives.