

CHEM-E7190/2024: Exercise 11 Part 2/2 - Luenberger observer
[EXTRA]
- Solutions

1. Design a Luenberger observer for the following state-space system. Implement the code and simulate the system in Matlab.

$$x(k+1) = \begin{bmatrix} 1.8097 & -0.8187 \\ 1 & 0 \end{bmatrix} x(k) + \begin{bmatrix} 0.5 \\ 0 \end{bmatrix} u(k)$$

$$y(k) = [0.1810 \quad -0.1810] x(k) + [0] u(k)$$

Hint: First, check the observability of the system by computing the observability matrix. Then, select desired observer poles and use pole placement to compute the observer gain matrix L .

2. The dynamic equations of the stirred tank system in state-space form are the following:

$$\dot{x}(t) = \begin{bmatrix} -0.5 & 0 \\ 0 & -1 \end{bmatrix} x(t) + \begin{bmatrix} 1 & 0 & 0 \\ -0.1 & 1 & 1 \end{bmatrix} w(t)$$

$$y(t) = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} x(t) + \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} w(t)$$

Design a Luenberger observer for the system. Implement the code and simulate the system in Matlab.

Hint: Since all states are measured (as indicated by the identity matrix in C), consider modifying the problem by assuming one state is not measured. Then, compute the observability matrix and design the observer accordingly.

3. Calculate the observer gains for the following system when the desired characteristic equation is $(\lambda + 9)(\lambda + 10)$

$$\dot{x}(t) = \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t)$$

$$y(t) = [1 \quad 0] x(t)$$

Hint: Verify observability by constructing the observability matrix. Then, set up the characteristic equation of $(A - LC)$ and equate it to the desired characteristic equation to solve for the observer gains

$$L = \begin{bmatrix} l_1 \\ l_2 \end{bmatrix}$$

Solution

Observability

$$CA = [1 \quad 0] \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} = [-1 \quad 1]$$

$$\mathcal{O} = \begin{bmatrix} C \\ CA \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1 & 1 \end{bmatrix} \text{rank}(\mathcal{O}) = 2 = \mathcal{N}_x$$

Characteristic equation

$$A - LC = \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} - \begin{bmatrix} l_1 \\ l_2 \end{bmatrix} [1 \quad 0] = \begin{bmatrix} -1 - l_1 & 1 \\ 2 - l_2 & -4 \end{bmatrix}$$

$$|\lambda I - (A - LC)| = \begin{vmatrix} \lambda + 1 + l_1 & -1 \\ -2 + l_2 & \lambda + 4 \end{vmatrix}$$

$$(\lambda + 1 + l_1)(\lambda + 4) - (-1)(-2 + l_2) = \lambda^2 + (5 + l_1)\lambda + 4(1 + l_1) + l_2 - 2$$

Luenberger Chapter 2 Exercise Answer

LP Steffe



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Table of Contents Luenberger Chapter 2 Exercise Answer

1. Understanding the eBook Luenberger Chapter 2 Exercise Answer
 - The Rise of Digital Reading Luenberger Chapter 2 Exercise Answer
 - Advantages of eBooks Over Traditional Books
2. Identifying Luenberger Chapter 2 Exercise Answer
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Luenberger Chapter 2 Exercise Answer
 - User-Friendly Interface
4. Exploring eBook Recommendations from Luenberger Chapter 2 Exercise Answer
 - Personalized Recommendations
 - Luenberger Chapter 2 Exercise Answer User Reviews and Ratings
 - Luenberger Chapter 2 Exercise Answer and Bestseller Lists
5. Accessing Luenberger Chapter 2 Exercise Answer Free and Paid eBooks
 - Luenberger Chapter 2 Exercise Answer Public Domain eBooks
 - Luenberger Chapter 2 Exercise Answer eBook Subscription Services

- Luenberger Chapter 2 Exercise Answer Budget-Friendly Options
- 6. Navigating Luenberger Chapter 2 Exercise Answer eBook Formats
 - ePub, PDF, MOBI, and More
 - Luenberger Chapter 2 Exercise Answer Compatibility with Devices
 - Luenberger Chapter 2 Exercise Answer Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Luenberger Chapter 2 Exercise Answer
 - Highlighting and Note-Taking Luenberger Chapter 2 Exercise Answer
 - Interactive Elements Luenberger Chapter 2 Exercise Answer
- 8. Staying Engaged with Luenberger Chapter 2 Exercise Answer
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Luenberger Chapter 2 Exercise Answer
- 9. Balancing eBooks and Physical Books Luenberger Chapter 2 Exercise Answer
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Luenberger Chapter 2 Exercise Answer
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Luenberger Chapter 2 Exercise Answer
 - Setting Reading Goals Luenberger Chapter 2 Exercise Answer
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Luenberger Chapter 2 Exercise Answer
 - Fact-Checking eBook Content of Luenberger Chapter 2 Exercise Answer
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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