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.

$$x(k+1) = \begin{bmatrix} 1.8097 & -0.8187 \\ 1 & 0 \end{bmatrix} x(k) + \begin{bmatrix} 0.5 \\ 0 \end{bmatrix} u(k)$$
$$y(k) = \begin{bmatrix} 0.1810 & -0.1810 \end{bmatrix} x(k) + \begin{bmatrix} 0 \end{bmatrix} u(k)$$

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 $(\lambda + 9)(\lambda + 10)$

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

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

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

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

Characteristic equation

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

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

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

1

Luenberger Chapter 2 Exercise Answer

Thomas Höglund

Luenberger Chapter 2 Exercise Answer:

Observers in Control Systems George Ellis,2002-10-16 Observers are digital algorithms that combine sensor outputs with knowledge of the system to provide results superior to traditional structures which rely wholly on sensors Observers have been used in selected industries for years but most books explain them with complex mathematics Observers in Control Systems uses intuitive discussion software experiments and supporting analysis to explain the advantages and disadvantages of observers If you are working in controls and want to improve your control systems observers could be the technology you need and this book will give you a clear thorough explanation of how they work and how to use them Control systems and devices have become the most essential part of nearly all mechanical systems machines devices and manufacturing systems throughout the world Increasingly the efficiency of production the reliability of output and increased energy savings are a direct result of the quality and deployment of the control system A modern and essential tool within the engineer s kit is the Observer which helps improve the performance and reduce the cost of these systems George Ellis is the author of the highly successful Control System Design Guide Second Edition Unlike most controls books which are written by control theorists and academics Ellis is a leading engineer designer author and lecturer working in industry directly with the users of industrial motion control systems Observers in Control Systems is written for all professional engineers and is designed to be utilized without an in depth background in control theory This is a real world book which will demonstrate how observers work and how they can improve your control system It also shows how observers operate when conditions are not ideal and teaches the reader how to quickly tune an observer in a working system Software Available online A free updated and enhanced version of the author s popular Visual ModelQ allows the reader to practice the concepts with Visual ModelQ models on a PC Based on a virtual laboratory all key topics are demonstrated with more than twenty control system models The models are written in Visual ModelQ and are available on the Internet to every reader with a PC Teaches observers and Kalman filters from an intuitive perspective Explains how to reduce control system susceptibility to noise Shows how to design an adaptive controller based on estimating parameter variation using observers Shows how to improve a control system s ability to reject disturbances Key topics are demonstrated with PC based models of control systems The models are written in both MatLab and ModelQ models are available free of charge   *Dynamic Economic Analysis* Milton Harris,1987 In industrial organization and labour economics many of the most interesting recent contributions have encompassed explicit dynamics as well as extensive form games This book collects and explains a number of the most widely used techniques in dynamic economic analysis   **Mathematical Methods for Neural Network Analysis and Design** Richard M. Golden,1996 For convenience many of the proofs of the key theorems have been rewritten so that the entire book uses a relatively uniform notion   *Geostatistics for Engineers and Earth Scientists* Ricardo A. Olea,2012-12-06 Engineers and earth scientists are increasingly interested in quantitative methods for the analysis interpretation and modeling of data that

imperfectly describe natural processes or attributes measured at geographical locations Inference from imperfect knowledge is the realm of classical statistics In the case of many natural phenomena auto and cross correlation preclude the use of classical statistics The appropriate choice in such circumstances is geostatistics a collection of numerical techniques for the characterization of spatial attributes similar to the treatment in time series analysis of auto correlated temporal data As in time series analysis most geostatistical techniques employ random variables to model the uncertainty that goes with the assessments The applicability of the methods is not limited by the physical nature of the attributes Geostatistics for Engineers and Earth Scientists presents a concise introduction to geostatistics with an emphasis on detailed explanations of methods that are parsimonious nonredundant and through the test of time have proved to work satisfactorily for a variety of attributes and sampling schemes Most of these methods are various forms of kriging and stochastic simulation The presentation follows a modular approach making each chapter as self contained as possible thereby allowing for reading of individual chapters reducing excessive cross referencing to previous results and offering possibilities for reviewing similar derivations under slightly different circumstances Guidelines and rules are offered wherever possible to help choose from among alternative methods and to select parameters thus relieving the user from making subjective calls based on an experience that has yet to be acquired Geostatistics for Engineers and Earth Scientists is intended to assist in the formal teaching of geostatistics or as a self tutorial for anybody who ismotivated to employ geostatistics for sampling design data analysis or natural resource characterization Real data sets are used to illustrate the application of the methodology

Introduction to Modern Economic Growth Daron Acemoglu,2008-12-15 From Nobel Prize winning economist Daron Acemoglu an incisive introduction to economic growth Introduction to Modern Economic Growth is a groundbreaking text from one of today s leading economists Daron Acemoglu gives graduate students not only the tools to analyze growth and related macroeconomic problems but also the broad perspective needed to apply those tools to the big picture questions of growth and divergence And he introduces the economic and mathematical foundations of modern growth theory and macroeconomics in a rigorous but easy to follow manner After covering the necessary background on dynamic general equilibrium and dynamic optimization the book presents the basic workhorse models of growth and takes students to the frontier areas of growth theory including models of human capital endogenous technological change technology transfer international trade economic development and political economy The book integrates these theories with data and shows how theoretical approaches can lead to better perspectives on the fundamental causes of economic growth and the wealth of nations Innovative and authoritative this book is likely to shape how economic growth is taught and learned for years to come Introduces all the foundations for understanding economic growth and dynamic macroeconomic analysis Focuses on the big picture questions of economic growth Provides mathematical foundations Presents dynamic general equilibrium Covers models such as basic Solow neoclassical growth and overlapping generations as well as models of endogenous technology

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Mathematical Analysis for Economists Knut Sydsæter,1981 Differential equations of first order Complex numbers Algebraic equations Topics in the theory of functions of several variables Integration Static optimization theory Differential equations of higher order Difference equations   *UMAP Modules* ,1988

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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

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