

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.

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

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:

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

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 $(\lambda + 5)(\lambda + 10)$

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

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

$$\begin{aligned}CA &= [1 \quad 0] \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} = [-1 \quad 1] \\ O &= \begin{bmatrix} C \\ CA \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1 & 1 \end{bmatrix} \text{rank}(O) = 2 = N_o\end{aligned}$$

Characteristic equation

$$\begin{aligned}A - LC &= \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} - \begin{bmatrix} l_1 \\ l_2 \end{bmatrix} [1 \quad 0] = \begin{bmatrix} -1-l_1 & 1 \\ 2-l_2 & -4 \end{bmatrix} \\ |\lambda I - (A - LC)| &= \begin{vmatrix} \lambda + 1 + l_1 & -1 \\ -2 + l_2 & \lambda + 4 \end{vmatrix} \\ (\lambda + 1 + l_1)(\lambda + 4) - (-1)(-2 + l_2) &= \lambda^2 + (5 + l_1)\lambda + 4(1 + l_1) + l_2 - 2\end{aligned}$$

Luenberger Chapter 2 Exercise Answer

Ricardo A. Olea



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 notation.

Nonlinear Programming Mokhtar S. Bazaraa, Hanif D. Sherali, C. M. Shetty, 2013-06-12. COMPREHENSIVE COVERAGE OF NONLINEAR PROGRAMMING THEORY AND ALGORITHMS THOROUGHLY REVISED.

AND EXPANDED Nonlinear Programming Theory and Algorithms now in an extensively updated Third Edition addresses the problem of optimizing an objective function in the presence of equality and inequality constraints Many realistic problems cannot be adequately represented as a linear program owing to the nature of the nonlinearity of the objective function and or the nonlinearity of any constraints The Third Edition begins with a general introduction to nonlinear programming with illustrative examples and guidelines for model construction Concentration on the three major parts of nonlinear programming is provided Convex analysis with discussion of topological properties of convex sets separation and support of convex sets polyhedral sets extreme points and extreme directions of polyhedral sets and linear programming Optimality conditions and duality with coverage of the nature interpretation and value of the classical Fritz John FJ and the Karush Kuhn Tucker KKT optimality conditions the interrelationships between various proposed constraint qualifications and Lagrangian duality and saddle point optimality conditions Algorithms and their convergence with a presentation of algorithms for solving both unconstrained and constrained nonlinear programming problems Important features of the Third Edition include New topics such as second interior point methods nonconvex optimization nondifferentiable optimization and more Updated discussion and new applications in each chapter Detailed numerical examples and graphical illustrations Essential coverage of modeling and formulating nonlinear programs Simple numerical problems Advanced theoretical exercises The book is a solid reference for professionals as well as a useful text for students in the fields of operations research management science industrial engineering applied mathematics and also in engineering disciplines that deal with analytical optimization techniques The logical and self contained format uniquely covers nonlinear programming techniques with a great depth of information and an abundance of valuable examples and illustrations that showcase the most current advances in nonlinear problems

Mathematical Asset Management Thomas Höglund, 2008-05-23 A practical approach to the mathematical tools needed to increase portfolio growth learn successful trading strategies and manage the risks associated with market fluctuation Mathematical Asset Management presents an accessible and practical introduction to financial derivatives and portfolio selection while also acting as a basis for further study in mathematical finance Assuming a fundamental background in calculus real analysis and linear algebra the book uses mathematical tools only as needed and provides comprehensive yet concise coverage of various topics such as Interest rates and the connection between present value and arbitrage Financial instruments beyond bonds that serve as building blocks for portfolios Trading strategies and risk performance measures Stochastic properties of stock prices The difference between expected return and expected growth and the geometric Brownian motion Diversification through the creation of optimal portfolios under various constraints The use of the Capital Asset Pricing Model to accurately estimate the difference between the return of the market and the short rate To further demonstrate the reality of the discussed concepts the author analyzes five active stocks over a four year period and highlights the different methods and portfolios that exist in today s economic world Exercises are also provided throughout

the text along with the solutions allowing readers to measure their understanding of presented techniques as well as see how the methods work in real life Mathematical Asset Management is an excellent book for courses in mathematical finance actuarial mathematics financial derivatives and financial engineering at the upper undergraduate and graduate levels It is also a valuable reference for practitioners in banking insurance and asset management industries

Numerical Methods in Finance and Economics Paolo Brandimarte, 2013-06-06 A state of the art introduction to the powerful mathematical and statistical tools used in the field of finance The use of mathematical models and numerical techniques is a practice employed by a growing number of applied mathematicians working on applications in finance Reflecting this development Numerical Methods in Finance and Economics A MATLAB Based Introduction Second Edition bridges the gap between financial theory and computational practice while showing readers how to utilize MATLAB the powerful numerical computing environment for financial applications The author provides an essential foundation in finance and numerical analysis in addition to background material for students from both engineering and economics perspectives A wide range of topics is covered including standard numerical analysis methods Monte Carlo methods to simulate systems affected by significant uncertainty and optimization methods to find an optimal set of decisions Among this book's most outstanding features is the integration of MATLAB which helps students and practitioners solve relevant problems in finance such as portfolio management and derivatives pricing This tutorial is useful in connecting theory with practice in the application of classical numerical methods and advanced methods while illustrating underlying algorithmic concepts in concrete terms Newly featured in the Second Edition In depth treatment of Monte Carlo methods with due attention paid to variance reduction strategies New appendix on AMPL in order to better illustrate the optimization models in Chapters 11 and 12 New chapter on binomial and trinomial lattices Additional treatment of partial differential equations with two space dimensions Expanded treatment within the chapter on financial theory to provide a more thorough background for engineers not familiar with finance New coverage of advanced optimization methods and applications later in the text Numerical Methods in Finance and Economics A MATLAB Based Introduction Second Edition presents basic treatments and more specialized literature and it also uses algebraic languages such as AMPL to connect the pencil and paper statement of an optimization model with its solution by a software library Offering computational practice in both financial engineering and economics fields this book equips practitioners with the necessary techniques to measure and manage risk

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 is motivated 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 and international linkages Addresses frontier research areas such as international linkages international trade political economy and economic development and structural change An accompanying Student Solutions Manual containing the answers to selected exercises is available 978 0 691 14163 3 24 95 See <https://press.princeton.edu/titles/8970.html> For Professors only To access a complete solutions manual online email us at acemoglusolutions@press.princeton.edu

princeton.edu Modern Control Systems Analysis and Design Walter J. Grantham, Thomas L. Vincent, 1993-01-26 An introduction to analysis techniques used in the design of linear feedback control systems with emphasis on both classical and matrix methods This text presents all design methods in a building block sequence including a thorough analysis of first and second order systems as well as general state space systems **Deterministic Observation Theory and Applications** Jean-Paul Gauthier, Ivan Kupka, 2001-10-08 This 2001 book presents a general theory as well as a constructive methodology to solve observation problems that is reconstructing the full information about a dynamical process on the basis of partial observed data A general methodology to control processes on the basis of the observations is also developed Illustrative but also practical applications in the chemical and petroleum industries are shown This book is intended for use by scientists in the areas of automatic control mathematics chemical engineering and physics **Numerical Analysis** Lee W. Johnson, Ronald Dean Riess, 1982 **Elementary Differential Equations with Boundary Value Problems** David L. Powers, 1985 *UMAP Modules* COMAP, 1990 **A Concrete Approach to Mathematical Modelling** Mike Mesterton-Gibbons, 2007-05-18 Critical praise for A Concrete Approach to Mathematical Modelling a treasure house of material for students and teachers alike can be dipped into regularly for inspiration and ideas It deserves to become a classic London Times Higher Education Supplement The author succeeds in his goal of serving the needs of the undergraduate population who want to see mathematics in action and the mathematics used is extensive and provoking SIAM Review Each chapter discusses a wealth of examples ranging from old standards to novelty Each model is developed critically analyzed critically and assessed critically Mathematical Reviews Mike Mesterton Gibbons has done what no author before him could he has written an in depth systematic guide to the art and science of mathematical modelling that is a great read from first page to last With an abundance of both wit and common sense he shows readers exactly how the modelling process works using fascinating real life examples from virtually every realm of human machine natural and cosmic activity You ll find models for determining how fast cars drive through a tunnel how many workers industry should employ the length of a supermarket checkout line how birds should select worms the best methods for avoiding an automobile accident and when a barber should hire an assistant just to name a few Offering more examples more detailed explanations and by far more sheer enjoyment than any other book on the subject A Concrete Approach to Mathematical Modelling is the ultimate how to guide for students and professionals in the hard sciences social sciences engineering computers statistics economics politics business management and every other discipline in which mathematical modelling plays a role An Instructor s Manual presenting detailed solutions to all the problems in the book is available upon request from the Wiley editorial department Cover Design Illustration Keithley Associates Inc **A Course in Fuzzy Systems and Control** Li-Xin Wang, 1997 Textbook **Mathematical Economics and Operations Research** Joseph Zarembka, 1978 **Nonlinear Programming** Dimitri P. Bertsekas, 1999 Topics in Mathematical Analysis for Economists Knut Sydsæter, 1981 Differential equations of first order

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