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:

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

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

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

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

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

Characteristic equation

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

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

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

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Linear Optimization and Approximation K. Glashoff,S.-A. Gustafson,2012-12-06 A linear optimization problem is the task of minimizing a linear real valued function of finitely many variables subject to linear con straints in general there may be infinitely many constraints This book is devoted to such problems Their mathematical properties are investi gated and algorithms for their computational solution are presented Applications are discussed in detail Linear optimization problems are encountered in many areas of appli cations They have therefore been subject to mathematical analysis for a long time We mention here only two classical topics from this area the so called uniform approximation of functions which was used as a mathematical tool by Chebyshev in 1853 when he set out to design a crane and the theory of systems of linear inequalities which has already been studied by Fourier in 1823 We will not treat the historical development of the theory of linear optimization in detail However we point out that the decisive break through occurred in the middle of this century It was urged on by the need to solve complicated decision problems where the optimal deployment of military and civilian resources had to be determined The availability of electronic computers also played an important role The principal computational scheme for the solution of linear optimization problems the simplex algorithm was established by Dantzig about 1950 In addi tion the fundamental theorems on such problems were rapidly developed based on earlier published results on the properties of systems of linear inequalities   **Computer Aided Design of Multivariable Technological Systems** G. G. Leininger,2014-05-16 Computer Aided Design of Multivariable Technological Systems covers the proceedings of the Second International Federation of Automatic Control IFAC The book reviews papers that discuss topics about the use of Computer Aided Design CAD in designing multivariable system such as theoretical issues applications and implementations The book tackles several topics relevant to the use of CAD in designing multivariable systems Topics include quasi classical approach to multivariable feedback system designs fuzzy control for multivariable systems root loci with multiple gain parameters multivariable frequency domain stability criteria and computational algorithms for pole assignment in linear multivariable systems The text will be of great use to professionals whose work involves designing and implementing multivariable systems

Quantitative Equity Portfolio Management Ludwig B. Chincarini,Daehwan Kim,2010-08-18 Quantitative Equity Portfolio Management brings the orderly structure of fundamental asset management to the often chaotic world of active equity management Straightforward and accessible it provides you with nuts and bolts details for selecting and aggregating factors building a risk model and much more   Observer Design for Nonlinear Systems Pauline Bernard,2019-02-01 Observer Design for Nonlinear Systems deals with the design of observers for the large class of nonlinear continuous time models It contains a unified overview of a broad range of general designs including the most recent results and their proofs such as the homogeneous and nonlinear Luenberger design techniques The book starts from the observation that most observer designs consist in looking for a reversible change of coordinates transforming the expression of the system

dynamics into some specific structures called normal forms for which an observer is known Therefore the problem of observer design is broken down into three sub problems What are the available normal forms and their associated observers Under which conditions can a system be transformed into one of these forms and through which transformation How can an inverse transformation that recovers an estimate in the given initial coordinates be achieved This organisation allows the book to structure results within a united framework highlighting the importance of the choice of the observer coordinates for nonlinear systems In particular the first part covers state affine forms with their Luenberger or Kalman designs and triangular forms with their homogeneous high gain designs The second part addresses the transformation into linear forms through linearization by output injection or in the context of a nonlinear Luenberger design and into triangular forms under the well known uniform and differential observability assumptions Finally the third part presents some recently developed methods for avoiding the numerically challenging inversion of the transformation Observer Design for Nonlinear Systems addresses students and researchers looking for an introduction to or an overview of the state of the art in observer design for nonlinear continuous time dynamical systems The book gathers the most important results focusing on a large and diffuse literature on general observer designs with global convergence and is a valuable source of information for academics and practitioners **A Course in Microeconomic Theory** David M. Kreps,2020-05-26 David M Kreps has developed a text in microeconomics that is both challenging and user friendly The work is designed for the first year graduate microeconomic theory course and is accessible to advanced undergraduates as well Placing unusual emphasis on modern noncooperative game theory it provides the student and instructor with a unified treatment of modern microeconomic theory one that stresses the behavior of the individual actor consumer or firm in various institutional settings The author has taken special pains to explore the fundamental assumptions of the theories and techniques studied pointing out both strengths and weaknesses The book begins with an exposition of the standard models of choice and the market with extra attention paid to choice under uncertainty and dynamic choice General and partial equilibrium approaches are blended so that the student sees these approaches as points along a continuum The work then turns to more modern developments Readers are introduced to noncooperative game theory and shown how to model games and determine solution concepts Models with incomplete information the folk theorem and reputation and bilateral bargaining are covered in depth Information economics is explored next A closing discussion concerns firms as organizations and gives readers a taste of transaction cost economics **Linear Controller Design** Stephen P. Boyd,Craig H. Barratt,1991 *Nonlinear Industrial Control Systems* Michael J. Grimble,Paweł Majecki,2020-05-19 Nonlinear Industrial Control Systems presents a range of mostly optimisation based methods for severely nonlinear systems it discusses feedforward and feedback control and tracking control systems design The plant models and design algorithms are provided in a MATLAB toolbox that enable both academic examples and industrial application studies to be repeated and evaluated taking into account practical application and implementation

problems The text makes nonlinear control theory accessible to readers having only a background in linear systems and concentrates on real applications of nonlinear control It covers different ways of modelling nonlinear systems including state space polynomial based linear parameter varying state dependent and hybrid design techniques for nonlinear optimal control including generalised minimum variance model predictive control quadratic Gaussian factorised and H design methods design philosophies that are suitable for aerospace automotive marine process control energy systems robotics servo systems and manufacturing steps in design procedures that are illustrated in design studies to define cost functions and cope with problems such as disturbance rejection uncertainties and integral wind up and baseline non optimal control techniques such as nonlinear Smith predictors feedback linearization sliding mode control and nonlinear PID Nonlinear Industrial Control Systems is valuable to engineers in industry dealing with actual nonlinear systems It provides students with a comprehensive range of techniques and examples for solving real nonlinear control design problems **Multivariable Technological Systems** D.P. Atherton,2014-06-28 Recent results in the development and application of analysis and design techniques for the control of multivariable systems are discussed in this volume Quantitative Investment Analysis Richard A. DeFusco,Dennis W. McLeavey,Jerald E. Pinto,David E. Runkle,Mark J. P. Anson,2015-10-15 Your complete guide to quantitative analysis in the investment industry Quantitative Investment Analysis Third Edition is a newly revised and updated text that presents you with a blend of theory and practice materials to guide you through the use of statistics within the context of finance and investment With equal focus on theoretical concepts and their practical applications this approachable resource offers features such as learning outcome statements that are targeted at helping you understand retain and apply the information you have learned Throughout the text s chapters you explore a wide range of topics such as the time value of money discounted cash flow applications common probability distributions sampling and estimation hypothesis testing and correlation and regression Applying quantitative analysis to the investment process is an important task for investment pros and students A reference that provides even subject matter treatment consistent mathematical notation and continuity in topic coverage will make the learning process easier and will bolster your success Explore the materials you need to apply quantitative analysis to finance and investment data even if you have no previous knowledge of this subject area Access updated content that offers insight into the latest topics relevant to the field Consider a wide range of subject areas within the text including chapters on multiple regression issues in regression analysis time series analysis and portfolio concepts Leverage supplemental materials including the companion Workbook and Instructor s Manual sold separately Quantitative Investment Analysis Third Edition is a fundamental resource that covers the wide range of quantitative methods you need to know in order to apply quantitative analysis to the investment process **Numerical Analysis** Lee W. Johnson,Ronald Dean Riess,1982 **Input-output Analysis** Heinz D. Kurz,Erik Dietzenbacher,Christian Lager,1998 Over the years the theoretical structure of input output analysis has been refined and its applications have been

widened This three volume set presents an overview of this development and an assessment of the current state of the subject It offers a comprehensive collection of previously published articles which present some of the most significant theoretical and empirical contributions of leading scholars to multisectoral economic analysis The first volume is devoted to the foundations of input output analysis to dynamic models and to multisectoral extensions of the multiplier principle Volume II explores approaches to the modelling of economics and the environment to the analysis of foreign trade and to regional and interregional economic activities The third volume discusses the methodologies developed for the investigation of economic structures offers an analysis of various versions of price models and investigates the problems related to the estimation of input output data **Modern Control Systems** Richard C. Dorf,Robert H. Bishop,2005 Written to be equally useful for all engineering disciplines this book is organized around the concept of control systems theory as it has been developed in the frequency and time domains It provides coverage of classical control employing root locus design frequency and response design using Bode and Nyquist plots It also covers modern control methods based on state variable models including pole placement design techniques with full state feedback controllers and full state observers The book covers several important topics including robust control systems and system sensitivity state variable models controllability and observability computer control systems internal model control robust PID controllers and computer aided design and analysis For all types of engineers who are interested in a solid introduction to control systems **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 **Mathematical Reviews** ,2004 **Energy Research Abstracts** ,1988 SIAM Journal on Matrix Analysis and Applications ,1997 **Quantitative Planning and Control** Yuji Ijiri,Andrew B. Whinston,1979 **Mathematics of Operations Research** ,1980 **Advances in Spectrum Analysis and Array Processing** Simon S. Haykin,1991 This is the second of a two volume set providing detailed discussion of fundamental issues in spectrum analysis and array processing detailed treatments of popular and new algorithms in these fields and coverage of applications relevant to them **Microeconomic Theory** David G. Luenberger,1995

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Table of Contents Luenberger Chapter Solutions Exercise 12

1. Understanding the eBook Luenberger Chapter Solutions Exercise 12
    - The Rise of Digital Reading Luenberger Chapter Solutions Exercise 12
    - Advantages of eBooks Over Traditional Books
2. Identifying Luenberger Chapter Solutions Exercise 12
    - 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 Solutions Exercise 12
    - User-Friendly Interface
4. Exploring eBook Recommendations from Luenberger Chapter Solutions Exercise 12
    - Personalized Recommendations
    - Luenberger Chapter Solutions Exercise 12 User Reviews and Ratings
    - Luenberger Chapter Solutions Exercise 12 and Bestseller Lists
5. Accessing Luenberger Chapter Solutions Exercise 12 Free and Paid eBooks

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