

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

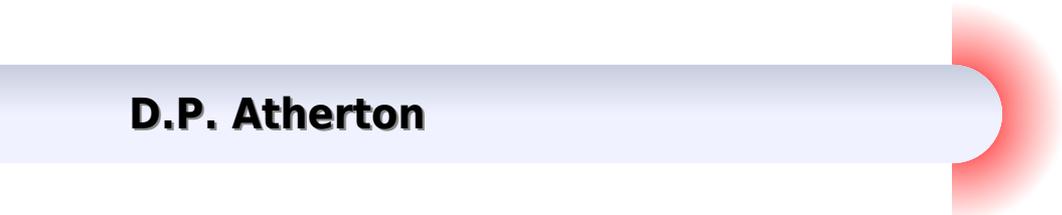
$$A - LC = \begin{bmatrix} -1 & 1 \\ 2 & -4 \end{bmatrix} - \begin{bmatrix} l_1 \\ l_2 \end{bmatrix} [1 \quad 0] = \begin{bmatrix} -1 - l_1 & 1 \\ 2 - l_2 & -4 \end{bmatrix}$$

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

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

Luenberger Chapter 3 Solutions Exercise 12

D.P. Atherton



Luenberger Chapter 3 Solutions Exercise 12:

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

Quarterly Review - Federal Reserve Bank of Minneapolis Federal Reserve Bank of Minneapolis,1985 *Augmented Lagrangian and Operator-splitting Methods in Nonlinear Mechanics* Ronald Glowinski,Patrick Le Tallec,1989-01-01 A need for a deeper understanding of the convergence properties of augmented Lagrangian algorithms and of their relationship to operator splitting methods such as alternating methods direction and the development of more efficient algorithms prompted the authors to write this book The volume is oriented to applications in continuum mechanics This volume deals with the numerical simulation of the behavior of continuous media by augmented Lagrangian and operator splitting methods coupled to finite element approximations It begins with a description of the mechanical and mathematical frameworks of the considered applications as well as a general analysis of the basic numerical methods additionally used to study them These ideas are then applied to specific classes of mechanical problems **Stability, Control and Application of Time-Delay Systems** Qingbin Gao,Hamid Reza Karimi,2019-06-27 Stability Control and Application of Time Delay Systems gives a systematic description of these systems It includes adequate designs of integrated modeling and control and frequency

characterizations Common themes revolve around creating certain synergies of modeling analysis control computing and applications of time delay systems that achieve robust stability while retaining desired performance quality The book provides innovative insights into the state of the art of time delay systems in both theory and practical aspects It has been edited with an emphasis on presenting constructive theoretical and practical methodological approaches and techniques Unifies existing and emerging concepts concerning time delay dynamical systems Provides a series of the latest results in large delay analysis and multi agent and thermal systems with delays Gives in each chapter numerical and simulation results in order to reflect the engineering practice Paper ,1994 **Analysis and Design of Descriptor Linear Systems**

Guang-Ren Duan,2010-09-14 Descriptor linear systems theory is an important part in the general field of control systems theory and has attracted much attention in the last two decades In spite of the fact that descriptor linear systems theory has been a topic very rich in content there have been only a few books on this topic This book provides a systematic introduction to the theory of continuous time descriptor linear systems and aims to provide a relatively systematic introduction to the basic results in descriptor linear systems theory The clear representation of materials and a large number of examples make this book easy to understand by a large audience General readers will find in this book a comprehensive introduction to the theory of descriptive linear systems Researchers will find a comprehensive description of the most recent results in this theory and students will find a good introduction to some important problems in linear systems theory *Journal of Dynamic Systems, Measurement, and Control* ,2001 Publishes theoretical and applied original papers in dynamic systems Theoretical papers present new theoretical developments and knowledge for controls of dynamical systems together with clear engineering motivation for the new theory Applied papers include modeling simulation and corroboration of theory with emphasis on demonstrated practicality *Proceedings of the Section on Survey Research Methods* American Statistical Association. Survey Research Methods Section,1990 Papers presented at the annual meeting of the American Statistical Association **Practical Bilevel Optimization** Jonathan F. Bard,2013-03-09 The use of optimization techniques has become integral to the design and analysis of most industrial and socio economic systems Great strides have been made recently in the solution of large scale problems arising in such areas as production planning airline scheduling government regulation and engineering design to name a few Analysts have found however that standard mathematical programming models are often inadequate in these situations because more than a single objective function and a single decision maker are involved Multiple objective programming deals with the extension of optimization techniques to account for several objective functions while game theory deals with the inter personal dynamics surrounding conflict Bilevel programming the focus of this book is in a narrow sense the combination of the two It addresses the problem in which two decision makers each with their individual objectives act and react in a noncooperative sequential manner The actions of one affect the choices and payoffs available to the other but neither player can completely dominate the other in the traditional sense

Nondifferentiable and Two-Level Mathematical Programming Kiyotaka Shimizu, Yo Ishizuka, Jonathan F. Bard, 2012-12-06

The analysis and design of engineering and industrial systems has come to rely heavily on the use of optimization techniques. The theory developed over the last 40 years coupled with an increasing number of powerful computational procedures has made it possible to routinely solve problems arising in such diverse fields as aircraft design, material flow, curve fitting, capital expansion, and oil refining, just to name a few. Mathematical programming plays a central role in each of these areas and can be considered the primary tool for systems optimization. Limits have been placed on the types of problems that can be solved though by the difficulty of handling functions that are not everywhere differentiable. To deal with real applications it is often necessary to be able to optimize functions that while continuous are not differentiable in the classical sense. As the title of the book indicates, our chief concern is with i) nondifferentiable mathematical programs and ii) two level optimization problems. In the first half of the book we study basic theory for general smooth and nonsmooth functions of many variables. After providing some background we extend traditional differentiable nonlinear programming to the nondifferentiable case. The term used for the resultant problem is nondifferentiable mathematical programming. The major focus is on the derivation of optimality conditions for general nondifferentiable nonlinear programs. We introduce the concept of the generalized gradient and derive Kuhn-Tucker type optimality conditions for the corresponding formulations.

Elementary Differential Equations with Boundary Value Problems David L. Powers, 1985

Winter Annual Meeting American Society of Mechanical Engineers, 1973

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.

Midwest Symposium on Circuits and Systems, 1978

Estimation of Poisson Parameters, Subject to Constraints Enio Galinkin, Jelihovschi, 1984

International Conference on Control '91, 25-28 March 1991, 1991

ICASSP 84, 1984

SWIEEEO Record of Technical Papers Institute of Electrical and Electronics Engineers. Region 5, 1970

Proceedings of the 24th IEEE Conference on Decision & Control, 1985

Journal of Physical Oceanography, 1984

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