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

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

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

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 Solutions Chapter 6

Katsuhisa Furuta,Akira Sano,Derek P. Atherton

Luenberger Solutions Chapter 6:

Nonlinear Functional Analysis and its Applications E. Zeidler,2013-12-11 As long as a branch of knowledge offers an abundance of problems it is full of vitality David Hilbert Over the last 15 years I have given lectures on a variety of problems in nonlinear functional analysis and its applications In doing this I have recommended to my students a number of excellent monographs devoted to specialized topics but there was no complete survey type exposition of nonlinear functional analysis making available a quick survey to the wide range of readers including mathematicians natural scientists and engineers who have only an elementary knowledge of linear functional analysis I have tried to close this gap with my five part lecture notes the first three parts of which have been published in the Teubner Texte series by Teubner Verlag Leipzig 1976 1977 and 1978 The present English edition was translated from a completely rewritten manuscript which is significantly longer than the original version in the Teubner Texte series The material is organized in the following way Part I Fixed Point Theorems Part II Monotone Operators Part III Variational Methods and Optimization Parts IV jV Applications to Mathematical Physics The exposition is guided by the following considerations a What are the supporting basic ideas and what intrinsic interrelations exist between them 3 In what relation do the basic ideas stand to the known propositions of classical analysis and linear functional analysis y What typical applications are there Vll Preface viii Special emphasis is placed on motivation

Control Engineering Solutions P. Albertos Pérez,Roland Strietzel,Neil Mort,1997 This book collects together in one volume a number of suggested control engineering solutions which are intended to be representative of solutions applicable to a broad class of control problems It is neither a control theory book nor a handbook of laboratory experiments but it does include both the basic theory of control and associated practical laboratory set ups to illustrate the solutions proposed

Local Stability and Ultimate Boundedness in the Control of Robot Manipulators Marco A. Arteaga,Alejandro Gutiérrez-Giles,Javier Pliego-Jiménez,2021-11-08 This book offers a unique compendium of the authors own research on the use of theoretical stability analysis showing how to take advantage of local stability design and ultimate boundedness for practical robot control It addresses researchers and postgraduate students dealing with control theory particularly with nonlinear systems Thanks to the numerous worked examples it could also be used as a textbook in postgraduate courses

Linear Multivariable Systems W. A. Wolovich,2012-12-06 This text was developed over a three year period of time 1971 1973 from a variety of notes and references used in the presentation of a senior first year graduate level course in the Division of En gineering at Brown University titled Linear System Theory The in tent of the course was not only to introduce students to the more modern state space approach to multivariable control system analysis and design as opposed to the classical frequency domain approach but also to draw analogies between the two approaches whenever and wherever possible It is therefore felt that the material presented will have broader appeal to practicing engineers than a text devoted exclusively to the state space approach It was assumed that students taking the course had also taken as a prerequisite an

undergraduate course in classical control theory and also were familiar with certain standard linear algebraic notions as well as the theory of ordinary differential equations although a substantial effort was expended to make the material as self contained as possible In particular Chapter 2 is employed to familiarize the reader with a good deal of the mathematical material employed through out the remainder of the text Chapters 3 through 5 were drawn in part from a number of contemporary state space and matrix algebraic references as well as some recent research of the author especially those portions which deal with polynomial matrices and the differential operator approach *H-infinity Control and Estimation of State-multiplicative Linear Systems* Eli Gershon,Uri Shaked,Isaac Yaesh,2005-06-24 Multiplicative noise appears in systems where the process or measurement noise levels depend on the system state vector Such systems are relevant for example in radar measurements where larger ranges involve higher noise level This monograph embodies a comprehensive survey of the relevant literature with basic problems being formulated and solved by applying various techniques including game theory linear matrix inequalities and Lyapunov parameter dependent functions Topics covered include convex H2 and H infinity norms analysis of systems with multiplicative noise state feedback control and state estimation of systems with multiplicative noise dynamic and static output feedback of stochastic bilinear systems tracking controllers for stochastic bilinear systems utilizing preview information Various examples which demonstrate the applicability of the theory to practical control engineering problems are considered two such examples are taken from the aerospace and guidance control areas

Formulating Principal-Agent Service Contracts for a Revenue Generating Unit Shuo Zeng,Moshe Dror,2015-07-02 This book examines contractual options for a performance based contract between an owner of a revenue generating unit and a repair agent for such unit The framework of the analysis is that of economists principal agent problem The contractual options of a principal and an agent are modeled as a Markov process with an undetermined time horizon For a risk neutral principal the authors identify the conditions under which a principal contracts with a risk neutral risk averse or risk seeking agent and derive the principal s optimal offer together with the agent s optimal service capacity response In essence the book provides an extensive formulating analysis of principal agent contracts given any exogenous parameter values Ultimately a small number of formulas cover a large spectrum of principal agent conditions **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   **Extremal Optimization** Yong-Zai Lu,Yu-Wang Chen,Min-Rong Chen,Peng Chen,Guo-Qiang Zeng,2018-09-03 Extremal Optimization Fundamentals Algorithms and Applications introduces state of the art extremal optimization EO and modified EO MEO solutions from fundamentals methodologies and algorithms to applications based on numerous classic publications and the authors recent original research results It promotes the movement of EO from academic study to practical applications The book covers four aspects beginning with a general review of real world optimization problems and popular solutions with a focus on computational complexity such as NP hard and the phase transitions occurring on the search landscape Next it introduces computational extremal dynamics and its applications in EO from principles mechanisms and algorithms to the experiments on some benchmark problems such as TSP spin glass Max SAT maximum satisfiability and graph partition It then presents studies on the fundamental features of search dynamics and mechanisms in EO with a focus on self organized optimization evolutionary probability distribution and structure features e g backbones which are based on the authors recent research results Finally it discusses applications of EO and MEO in multiobjective optimization systems modeling intelligent control and production scheduling The authors present the advanced features of EO in solving NP hard problems through problem formulation algorithms and simulation studies on popular benchmarks and industrial applications They also focus on the development of MEO and its applications This book can be used as a reference for graduate students research developers and practical engineers who work on developing optimization solutions for those complex systems with hardness that cannot be solved with mathematical optimization or other computational intelligence such as evolutionary computations   Journal of Applied Mechanics ,1975 Publishes original research in all branches of mechanics including aerodynamics aeroelasticity boundary layers computational mechanics constitutive modeling of materials dynamics elasticity flow and fracture heat transfer hydraulics impact internal flow mechanical properties of materials micromechanics plasticity stress analysis structures thermodynamics turbulence vibration and wave propagation   *Deterministic L2/H2 Optimization of Linear Dynamical Systems* Nader Safari-Shad,1992   **Implicit Linear Systems** J.Dwight Aplevich,1991-03-20 These notes are an introduction to implicit models of linear dynamical systems with applications to modelling control system design and identification intended for control system engineers at the beginning graduate level Because they are non oriented the models are particularly useful where causality is unknown or may change They are implicit in all variables and closed under the algebraic operations and hence are useful for computer aided analysis and design They possess the vector matrix conceptual simplicity and computational feasibility of state space equations together with the generality of matrix fraction descriptions and admit of canonical forms for which the joint identification of system parameters and dynamic variables is linear The notes simplify generalize and complement much recent work on singular or descriptor models but do not duplicate it Sections are included on realizations canonical forms minimal representations algebraic design applications quadratic

optimization identification large scale systems and extensions to multi dimensional and time varying systems   **Nonlinear Process Control** Michael A. Henson,Dale E. Seborg,1997 Nonlinear Process Control assembles the latest theoretical and practical research on design analysis and application of nonlinear process control strategies It presents detailed coverage of all three major elements of nonlinear process control identification controller design and state estimation Nonlinear Process Control reflects the contributions of eleven leading researchers in the field It is an ideal textbook for graduate courses in process control as well as a concise up to date reference for control engineers   *Applied Mechanics Reviews* ,1969   **Modal Control: Theory and Applications** Brian Porter,1972   **Rotating Machinery Dynamics** Agnieszka Muszyńska,J. E. Simonis,1987   **On-line Estimation and Adaptive Control of Bioreactors** G. Bastin,Denis Dochain,1990-07-03 This book deals with monitoring and control of biotechnological processes Different methods are proposed which are based on the nonlinear structure of the process and do not require any a priori knowledge of the fermentation parameters The theoretical stability and convergence properties of the proposed algorithms are analysed and their performances are illustrated by simulation results and in many instances by real life experiments The concept of software sensors is introduced these are algorithms based on the nonlinear model of the process and designed for on line estimation of the biological variables and or the fermentation parameters In order to deal with process nonstationarities and parameter uncertainties reference is made to adaptive estimation and control techniques The book is the result of an intensive joint research effort by the authors during the last decade It is intended as a graduate level text for students of bioengineering as well as a reference text for scientists and engineers involved in the design and optimization of bioprocesses   State Variable Methods in Automatic Control Katsuhisa Furuta,Akira Sano,Derek P. Atherton,1988-11-09 Using numerous worked examples and problems this book provides and introduction to the use of state space methods in control system analysis and design It has been written for those with a very basic background in linear control theory and linear algebra It provides physical insight into the various procedures considered as well as presenting the theoretical derivations State Variable Methods in Automatic Control will be of interest to students and lecturers involved with courses on control engineering specifically those involving state space methods It will also be valuable for professional engineers involved in systems and circuit theory as well as control system design   *Microeconomic Theory* David G. Luenberger,1995   *Journal of Dynamic Systems, Measurement, and Control* ,1979   **Static and Dynamic Finite Element Analysis of Finite Deformation Geometrically Exact Shell Models** Stanford University. Division of Applied Mechanics. Division of Applied Mechanics,1993

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Table of Contents Luenberger Solutions Chapter 6

1. Understanding the eBook Luenberger Solutions Chapter 6
    - The Rise of Digital Reading Luenberger Solutions Chapter 6
    - Advantages of eBooks Over Traditional Books
2. Identifying Luenberger Solutions Chapter 6
    - 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 Solutions Chapter 6
    - User-Friendly Interface
4. Exploring eBook Recommendations from Luenberger Solutions Chapter 6
    - Personalized Recommendations
    - Luenberger Solutions Chapter 6 User Reviews and Ratings
    - Luenberger Solutions Chapter 6 and Bestseller Lists

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web the hive the hive opened in 2016 and is a multi sensory experience designed to highlight the extraordinary life of bees it stands 17 metres 56 ft tall and is set in a wildflower meadow the hive was designed by english artist wolfgang buttress the hive has been created using thousands of aluminium pieces that are presented in the shape of

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web at a towering 17 metres tall the hive is a striking installation in the heart of a wildflower meadow that recreates life inside a beehive a stunning piece of contemporary art it s one of the most photographed spots in the gardens

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