Chapter 6: Eigenvalues and Eigenvectors

Problem 6.1 In each case, find

a. the corresponding matrix transformation which shows a counterclockwise rotation about the origin of the xy-plane. Explain in what sense this transformation is unique.

b. the corresponding matrix transformation which shows a reflection about the line $y = x$. Explain in what sense this transformation is unique.

Solution 6.1 We are looking for matrix transformations $\mathbf{x} \mapsto A\mathbf{x}$ of the form

$$x_1 = a_{11}x_1 + a_{12}x_2 = ax_1 + cx_2$$
$$x_2 = a_{21}x_1 + a_{22}x_2 = bx_1 + dx_2$$

We can determine the coefficients a, b, c, d by considering the effect of the transformation on the standard basis vectors $\mathbf{e}_1$ and $\mathbf{e}_2$. For example, if we want to find the matrix A that corresponds to a counterclockwise rotation of $\theta = 45°$, we can observe that $A\mathbf{e}_1 = \begin{bmatrix} \cos 45° \\ \sin 45° \end{bmatrix}$ and $A\mathbf{e}_2 = \begin{bmatrix} -\sin 45° \\ \cos 45° \end{bmatrix}$.

a. Without any other information, a_{11}, a_{12}, a_{21}, and a_{22} can take any values whatsoever.

Geometrically, a reflection in a line through the origin has the property that the vector $\mathbf{x}$ and its reflection $A\mathbf{x}$ are symmetric with respect to the line. In other words, the angle between $\mathbf{x}$ and the line is the same as the angle between $A\mathbf{x}$ and the line.

b. By drawing a picture, we see that $A\mathbf{e}_1 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ and $A\mathbf{e}_2 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$.

c. Geometrically, it is clear that a reflection about a line through the origin has the property that $A(A\mathbf{x}) = \mathbf{x}$ for all vectors $\mathbf{x}$ in $\mathbb{R}^2$. In other words, $A^2\mathbf{x} = \mathbf{x}$ for all $\mathbf{x}$ in $\mathbb{R}^2$. Therefore, $A^2 = I_2$. Algebraically, this means that $\begin{bmatrix} a & b \\ c & d \end{bmatrix}^2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$, which gives us the equations $a^2 + bc = 1$, $b(a+d) = 0$, $c(a+d) = 0$, and $bc + d^2 = 1$. Since $b = 0$ and $c = 1$ is a solution of this system, the reflection matrix A is not unique.

(c) Show that any reflection matrix A has the property that $A^2 = I_2$.

Solution 6.1 (c) Let $A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$ be a reflection matrix. Then $A^2 = \begin{bmatrix} a^2 + bc & b(a+d) \\ c(a+d) & bc + d^2 \end{bmatrix}$.

Since A is a reflection matrix, $A\mathbf{x}$ is the reflection of $\mathbf{x}$ about a line through the origin. Therefore, $A(A\mathbf{x}) = \mathbf{x}$ for all $\mathbf{x}$ in $\mathbb{R}^2$. In other words, $A^2\mathbf{x} = \mathbf{x}$ for all $\mathbf{x}$ in $\mathbb{R}^2$. Therefore, $A^2 = I_2$.

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Infinite Horizon Optimal Control Dean A. Carlson,Alain Haurie,2013-06-29 This monograph deals with various classes of deterministic continuous time optimal control problems wh ich are defined over unbounded time intervala For these problems the performance criterion is described by an improper integral and it is possible that when evaluated at a given admissible element this criterion is unbounded To cope with this divergence new optimality concepts referred to here as overtaking weakly overtaking agreeable plans etc have been proposed The motivation for studying these problems arisee primarily from the economic and biological aciences where models of this nature arise quite naturally since no natural bound can be placed on the time horizon when one considers the evolution of the state of a given economy or species The reeponsibility for the introduction of this interesting class of problems rests with the economiste who first studied them in the modeling of capital accumulation processes Perhaps the earliest of these was F Ramsey who in his seminal work on a theory of saving in 1928 considered a dynamic optimization model defined on an infinite time horizon Briefly this problem can be described as a Lagrange problem with unbounded time interval The advent of modern control theory particularly the formulation of the famoue Maximum Principle of Pontryagin has had a considerable impact on the treatment of these models as well as optimization theory in general Introduction to Nonlinear Control Christopher M. Kellett,Philipp Braun,2023-06-27 An introductory text on the analysis control and estimation of nonlinear systems appropriate for advanced undergraduate and graduate students This self contained and accessible introduction to the concepts and techniques used for nonlinear feedback systems offers a holistic treatment suitable for use in both advanced undergraduate and graduate courses students need only some familiarity with differential equations and linear algebra to understand the material presented The text begins with an overview of stability and Lyapunov methods for nonlinear systems with Lyapunov s second method revisited throughout the book as a connective thread Other introductory chapters cover linear systems frequency domain methods and discrete time systems Building on this background material the book provides a broad introduction to the basic ideas underpinning major themes of research in nonlinear control including input to state stability sliding mode control adaptive control feedback linearization and robust output regulation Chapters also cover observer design and estimation for nonlinear systems The text is notable for its coverage of nonlinear model predictive control and its introduction to the use of linear matrix inequalities and semidefinite programming coupled with their use in modern antiwindup designs First text on nonlinear control appropriate for undergraduates Suitable both for students preparing for rigorous graduate study and for those entering technical fields outside of academia Unique in its coverage of recent research topics Pedagogical features including extensive chapter summaries examples and appendixes with definitions results and MATLAB applications *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 Uncertainty, Production, Choice, and Agency Robert G. Chambers,John Quiggin,2000-09-18 This book presents a justification of the state contingent approach to the economics of uncertainty **Power Converters and AC Electrical Drives with Linear Neural Networks** Maurizio Cirrincione,Marcello Pucci,Gianpaolo Vitale,2017-12-19 The first book of its kind Power Converters and AC Electrical Drives with Linear Neural Networks systematically explores the application of neural networks in the field of power electronics with particular emphasis on the sensorless control of AC drives It presents the classical theory based on space vectors in identification discusses control of electrical drives and power converters and examines improvements that can be attained when using linear neural networks The book integrates power electronics and electrical drives with artificial neural networks ANN Organized into four parts it first deals with voltage source inverters and their control It then covers AC electrical drive control focusing on induction and permanent magnet synchronous motor drives The third part examines theoretical aspects of linear neural networks particularly the neural EXIN family The fourth part highlights original applications in electrical drives and power quality ranging from neural based parameter estimation and sensorless control to distributed generation systems from renewable sources and active power filters Simulation and experimental results are provided to validate the theories Written by experts in the field this state of the art book requires basic knowledge of electrical machines and power electronics as well as some familiarity with control systems signal processing linear algebra and numerical analysis Offering multiple paths through the material the text is suitable for undergraduate and postgraduate students theoreticians practicing engineers and researchers involved in applications of ANNs *Control in Bioprocessing* Pablo A. López Pérez,Ricardo Aguilar López,Ricardo Femat,2020-03-10 Closes the gap between bioscience and mathematics based process engineering This book presents the most commonly employed approaches in the control of bioprocesses It discusses the role that control theory plays in understanding the mechanisms of cellular and metabolic processes and presents key results in various fields such as dynamic modeling dynamic properties of bioprocess models software sensors designed for the online estimation of parameters and state variables and control and supervision of bioprocesses Control in Bioengineering and Bioprocessing Modeling Estimation and the Use of Sensors is divided into three sections Part I Mathematical preliminaries and overview of

the control and monitoring of bioprocess provides a general overview of the control and monitoring of bioprocesses and introduces the mathematical framework necessary for the analysis and characterization of bioprocess dynamics Part II Observability and control concepts presents the observability concepts which form the basis of design online estimation algorithms software sensor for bioprocesses and reviews controllability of these concepts including automatic feedback control systems Part III Software sensors and observer based control schemes for bioprocesses features six application cases including dynamic behavior of 3 dimensional continuous bioreactors observability analysis applied to 2D and 3D bioreactors with inhibitory and non inhibitory models and regulation of a continuously stirred bioreactor via modeling error compensation Applicable across all areas of bioprocess engineering including food and beverages biofuels and renewable energy pharmaceuticals and nutraceuticals fermentation systems product separation technologies wastewater and solid waste treatment technology and bioremediation Provides a clear explanation of the mass balance based mathematical modelling of bioprocesses and the main tools for its dynamic analysis Offers industry based applications on myco diesel for implementing quality of observability developing a virtual sensor based on the Just In Time Model to monitor biological control systems and virtual sensor design for state estimation in a photocatalytic bioreactor for hydrogen production Control in Bioengineering and Bioprocessing is intended as a foundational text for graduate level students in bioengineering as well as a reference text for researchers engineers and other practitioners interested in the field of estimation and control of bioprocesses **Instrumentation and Control Systems for Nuclear Power Plants** Mauro Cappelli,2023-03-21 Instrumentation and Control Systems for Nuclear Power Plants provides the latest innovative research onthe design of effective modern I C systems for both existing and newly commissioned plants along withinformation on system implementation Dr Cappelli and his team of expert contributors cover fundamentals explore the most advanced research in control systems technology and tackle topics such as the human machine interface control room redesign and control modeling The inclusion of codes and standards inspection procedures and regulatory issues ensure that the reader can confidently design their own I Csystems and integrate them into existing nuclear sites and projects Covers various viewpoints including theory modeling design and applications of I C systems Includes codes and standards inspection procedures and regulatory issues Combines engineering and physics aspects in one thorough resource presenting human factors modeling and HMI together for the first time Instrumentation and Control Systems for Nuclear Power Plants highlights the key role nuclear energy plays in the transition to a lower carbon energy mix **Using the Bootstrap Algorithm for Changing the Control Game** Petter Ogland,2018-03-22 Using the Bootstrap Algorithm for Changing the Control Game is clearly written and points are supported by real life case studies Dr Ogland demonstrates how a Total Quality Management strategy articulated through the use of bootstrap algorithms can be used to achieve world class performance in challenging environments such as complex organisations saturated with power struggles and internal politics The book features insights

on critical systems thinking game theory quality management systems the Efqm Business Excellence Model self assessment and the implementation of Tqm Case studies provide practical insights from twenty years of empirical research on how to bootstrap Tqm and Business Excellence in complex environments The ideas developed in the book have been acknowledged as a major contribution to the theory of Tqm and the book itself is an indispensable resource for practitioners trying to implement Tqm in environments where traditional implementation methods are bound to fail Financial Economics, Risk And Information (2nd Edition) Marcelo Bianconi,2011-11-29 Financial Economics Risk and Information presents the fundamentals of finance in static and dynamic frameworks with focus on risk and information The objective of this book is to introduce undergraduate and first year graduate students to the methods and solutions of the main problems in finance theory relating to the economics of uncertainty and information The main goal of the second edition is to make the materials more accessible to a wider audience of students and finance professionals The focus is on developing a core body of theory that will provide the student with a solid intellectual foundation for more advanced topics and methods The new edition has streamlined chapters and topics with new sections on portfolio choice under alternative information structures The starting point is the traditional mean variance approach followed by portfolio choice from first principles The topics are extended to alternative market structures alternative contractual arrangements and agency dynamic stochastic general equilibrium in discrete and continuous time attitudes towards risk and towards inter temporal substitution in discrete and continuous time and option pricing In general the book presents a balanced introduction to the use of stochastic methods in discrete and continuous time in the field of financial economics **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 *Numerical Methods for Linear Control Systems* Biswa Datta,2004 Numerical Methods for Linear Control Systems Design and Analysis is an interdisciplinary textbook aimed at systematic descriptions and implementations of numerically viable algorithms based on well established efficient and stable modern numerical linear techniques for mathematical problems arising in the design and analysis of linear control systems both for the first and second order models Unique coverage of modern mathematical concepts such as parallel computations second order systems and large scale solutions Background material in linear algebra numerical linear algebra and control theory included in text Step by step explanations of the algorithms and examples **Geophysical Inverse Theory** Robert L. Parker,1994-06-05 In many physical sciences the most natural description of a system is with a function of position or time In principle infinitely many numbers are needed to specify that function but in practice only finitely many measurements can be made Inverse theory concerns the mathematical techniques that enable researchers to use the available information to build a model of the unknown system or to determine its essential properties In Geophysical Inverse Theory Robert Parker provides a systematic development of inverse theory at the graduate and professional level that emphasizes a rigorous yet practical solution of

inverse problems with examples from experimental observations in geomagnetism seismology gravity electromagnetic sounding and interpolation Although illustrated with examples from geophysics this book has broad implications for researchers in applied disciplines from materials science and engineering to astrophysics oceanography and meteorology Parker s approach is to avoid artificial statistical constructs and to emphasize instead the reasonable assumptions researchers must make to reduce the ambiguity that inevitably arises in complex problems The structure of the book follows a natural division in the subject into linear theory in which the measured quantities are linear functionals of the unknown models and nonlinear theory which covers all other systems but is not nearly so well understood The book covers model selection as well as techniques for drawing firm conclusions about the earth independent of any particular model

Gradient Optimization and Nonlinear Control Lawrence Hasdorff,1976 **Parimutuel Applications In Finance** Ken Baron,Jeffrey Lange,2006-11-28 Financial intermediaries typically offer derivatives to their customers only when they can hedge the exposures from these transactions Baron and Lange show that parimutuel auctions can be used by financial intermediaries to offer derivatives without exposing themselves to risk *Linearization of Nonlinear Control Systems* Hong-Gi Lee,2022-09-02 This textbook helps graduate level student to understand easily the linearization of nonlinear control system Differential geometry is essential to understand the linearization problems of the control nonlinear systems In this book the basics of differential geometry needed in linearization are explained on the Euclidean space instead of the manifold for students who are not accustomed to differential geometry Many Lie algebra formulas used often in linearization are also provided with proof The conditions in the linearization problems are complicated to check because the Lie bracket calculation of vector fields by hand needs much concentration and time This book provides MATLAB programs for most of the theorems The book also includes end of chapter problems and other pedagogical aids to help understanding and self study

Computer Aided Design of Mechanical Systems United States. Army Materiel Command,1973 *Stability And Time-optimal Control Of Hereditary Systems: With Application To The Economic Dynamics Of The Us (2nd Edition)* Ethelbert Nwakuche Chukwu,2001-12-28 Stability and Time Optimal Control of Hereditary Systems is the mathematical foundation and theory required for studying in depth the stability and optimal control of systems whose history is taken into account In this edition the economic application is enlarged and explored in some depth The application holds out the hope that full employment and high income growth will be compatible with low prices and low inflation provided that the control matrix has full rank i e the existing controls are fully effectively used The book concludes with a new appendix containing complete programs data graphs and quantitative results for the US economy **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 Lanczos Algorithms for Large Symmetric Eigenvalue Computations Jane K. Cullum,Ralph A. Willoughby,1985-01-01 First published in 1985 Lanczos Algorithms for Large Symmetric Eigenvalue Computations Vol 1 Theory presents background material descriptions and supporting theory relating to practical numerical algorithms for the solution of huge eigenvalue problems This book deals with symmetric problems However in this book symmetric also encompasses numerical procedures for computing singular values and vectors of real rectangular matrices and numerical procedures for computing eigenelements of nondefective complex symmetric matrices Although preserving orthogonality has been the golden rule in linear algebra most of the algorithms in this book conform to that rule only locally resulting in markedly reduced memory requirements Additionally most of the algorithms discussed separate the eigenvalue singular value computations from the corresponding eigenvector singular vector computations This separation prevents losses in accuracy that can occur in methods which in order to be able to compute further into the spectrum use successive implicit deflation by computed eigenvector or singular vector approximations **The Dynamics Of A Capitalist Economy** Richard M. Goodwin,Lionel F. Punzo,2019-09-05 In this book Professor Goodwin eschewing fine scale minutiae or classical mechanics has addressed the big picture His work deals with the great issues of the class struggle a Ia Karl Marx predator prey dramas of the Lotka Volterra type von Neumann s magisterial model of autonomous growth Harrodian and Sraffian developments of Keynesian systems in their input output aspects or accelerator multiplier aspects Professor Lionello Punzo of a postwar generation provides additional chapters of multi sector dynamics working from and going beyond the aggregate models of Harrod Domar and Solow

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web represent two unsigned 2 bit numbers the outputs are the four bits of the product of the input numbers express the logic functions for each term in the product on a karnaugh map of the four input variables hence design a multiplier circuit using 4 input nand and inverter gates only a 3 a 2 a1 a0 0001 1100

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