Applied Optimal Estimation

Graduate-level text provides introduction to optimal control theory for stochastic systems, emphasizing application of basic concepts to real problems.
Annotation Rodgers (U. of Oxford) provides graduate students and other researchers a background to the inverse problem and its solution, with applications relating to atmospheric measurements. He introduces the stages in the reverse order than the usual approach in order to develop the learner's intuition about the nature of the inverse problem. Annotation copyrighted by Book News, Inc., Portland, OR.
This is the first book on the optimal estimation that places its major emphasis on practical applications, treating the subject more from an engineering than a mathematical orientation. Even so, theoretical and mathematical concepts are introduced and developed sufficiently to make the book a self-contained source of instruction for readers without prior knowledge of the basic principles of the field. The work is the product of the technical staff of The Analytic Sciences Corporation (TASC), an organization whose success has resulted largely from its applications of optimal estimation techniques to a wide variety of real situations involving large-scale systems. Arthur Gelb writes in the Foreword that "It is our intent throughout to provide a simple and interesting picture of the central issues underlying modern estimation theory and practice. Heuristic, rather than theoretically elegant, arguments are used extensively, with emphasis on physical insights and key questions of practical importance." Numerous illustrative examples, many based on actual applications, have been interspersed throughout the text to lead the student to a concrete understanding of the theoretical material. The inclusion of problems with "built-in" answers at the end of each of the nine chapters further enhances the self-study potential of the text. After a brief historical prelude, the book introduces the mathematics underlying random process theory and state-space characterization of linear dynamic systems. The theory and practice of optimal estimation is them presented, including filtering, smoothing, and prediction. Both linear and non-linear systems, and continuous- and discrete-time cases, are covered in considerable detail. New results are described concerning the application of covariance analysis to non-linear systems and the connection between observers and optimal estimators. The final chapters treat such practical and often pivotal issues as suboptimal structure, and computer loading considerations. This book is an outgrowth of a course given by TASC at a number of US Government facilities. Virtually all of the members of the TASC technical staff have, at one time and in one way or another, contributed to the material contained in the work.
Numerous examples highlight this treatment of the use of linear quadratic Gaussian methods for control system design. It explores linear optimal control theory from an engineering viewpoint, with illustrations of practical applications. Key topics include loop-recovery techniques, frequency shaping, and controller reduction. Numerous examples and complete solutions. 1990 edition.
Estimation and Control of Dynamical Systems
Theory Algorithms and Software
Optimal Control
Nonlinear Estimation
Applied Optimal Control

In 1960, R. E. Kalman published his celebrated paper on recursive min imum variance estimation in dynamical systems [14]. This paper, which introduced an algorithm that has since been known as the discrete Kalman filter, produced a virtual revolution in the field of systems engineering. Today, Kalman filters are used in such diverse areas as navigation, guid ance, oil drilling, water and air quality, and geodetic surveys. In addition, Kalman's work led to a multitude of books and papers on minimum vari ance estimation in dynamical systems, including one by Kalman and Bucy on continuous time systems [15]. Most of this work was done outside of the mathematics and statistics communities and, in the spirit of true academic parochialism, was, with a few notable exceptions, ignored by them. This text is my effort toward closing that chasm. For mathematics students, the Kalman filtering theorem is a beautiful illustration of functional analysis in action; Hilbert spaces being used to solve an extremely important problem in applied mathematics. For statistics students, the Kalman filter is a vivid example of Bayesian statistics in action. The present text grew out of a series of graduate courses given by me in the past decade. Most of these courses were given at the University of Mas sachusetts at Amherst.
"An excellent introduction to optimal control and estimation theory and its relationship with LQG design. . . . invaluable as a reference for those already familiar with the subject." — Automatica. This highly regarded graduate-level text provides a comprehensive introduction to optimal control theory for stochastic systems, emphasizing application of its basic concepts to real problems. The first two chapters introduce optimal control and review the mathematics of control and estimation. Chapter 3 addresses optimal control of systems that may be nonlinear and time-varying, but whose inputs and parameters are known without error. Chapter 4 of the book presents methods for estimating the dynamic states of a system that is driven by uncertain forces and is observed with random measurement error. Chapter 5 discusses the general problem of stochastic optimal control, and the concluding chapter covers linear time-invariant systems. Robert F. Stengel is Professor of Mechanical and Aerospace Engineering at Princeton University, where he directs the Topical Program on Robotics and Intelligent Systems and the Laboratory for Control and Automation. He was a principal designer of the Project Apollo Lunar Module control system. "An excellent teaching book with many examples and worked problems which would be ideal for self-study or for use in the classroom. . . . The book also has a practical orientation and would be of considerable use to people applying these techniques in practice." — Short Book Reviews, Publication of the International Statistical Institute. "An excellent book which guides the reader through most of the important concepts and techniques. . . . A useful book for students (and their teachers) and for those practicing engineers who require a comprehensive reference to the subject." — Library

Reviews, The Royal Aeronautical Society.
Nonlinear Estimation: Methods and Applications with Deterministic Sample Points focusses on a comprehensive treatment of deterministic sample point filters (also called Gaussian filters) and their variants for nonlinear estimation problems, for which no closed-form solution is available in general. Gaussian filters are becoming popular with the designers due to their ease of implementation and real time execution even on inexpensive or legacy hardware. The main purpose of the book is to educate the reader about a variety of available nonlinear estimation methods so that the reader can choose the right method for a real life problem, adapt or modify it where necessary and implement it. The book can also serve as a core graduate text for a course on state estimation. The book starts from the basic conceptual solution of a nonlinear estimation problem and provides an in depth coverage of (i) various Gaussian filters such as the unscented Kalman filter, cubature and quadrature based filters, Gauss-Hermite filter and their variants and (ii) Gaussian sum filter, in both discrete and continuous-discrete domain. Further, a brief description of filters for randomly delayed measurement and two case-studies are also included. Features: The book covers all the important Gaussian filters, including filters with randomly delayed measurements. Numerical simulation examples with detailed matlab code are provided for most algorithms so that beginners can verify their understanding. Two real world case studies are included: (i) underwater passive target tracking, (ii) ballistic target tracking. The style of writing is suitable for engineers and scientists. The material of the book is presented with the emphasis on key ideas, underlying assumptions, algorithms, and properties. The book combines rigorous mathematical treatment with matlab code, algorithm listings, flow charts and detailed case studies to deepen understanding.
Prior to the 1970's a substantial literature had accumulated on the theory of optimal design, particularly of optimal linear regression design. To a certain extent the study of the subject had been piecemeal, different criteria of optimality having been studied separately. Also to a certain extent the topic was regarded as being largely of theoretical interest and as having little value for the practising statistician. However during this decade two significant developments occurred. It was observed that the various different optimality criteria had several mathematical properties in common; and general algorithms for constructing optimal design measures were developed. From the first of these there emerged a general theory of remarkable simplicity and the second at least raised the possibility that the theory would have more practical value. With respect to the second point there does remain a limiting factor as far as designs that are optimal for parameter estimation are concerned, and this is that the theory assumes that the model be collected is known a priori. This of course underlying data to is seldom the case in practice and it often happens that designs which are optimal for parameter estimation allow no possibility of model validation. For this reason the theory of design for parameter estimation may well have to be combined with a theory of model validation before its practical potential is fully realized. Nevertheless discussion in this monograph is limited to the theory of design optimal for parameter estimation.
Theory and Practice
Estimation with Applications to Tracking and Navigation
Stochastic Models, Estimation, and Control
Optimal State Estimation
Optimal Filtering
This book provides a comprehensive presentation of classical and advanced topics in estimation and control of dynamical systems with an emphasis on stochastic control. Many aspects which are not easily found in a single text are provided, such as connections between control theory and mathematical finance, as well as differential games. The book is self-contained and prioritizes concepts rather than full rigor, targeting scientists who want to use control theory in their research in applied mathematics, engineering, economics, and management science. Examples and exercises are included throughout, which will be useful for PhD courses and graduate courses in general. Dr. Alain Bensoussan is Lars Magnus Ericsson Chair at UT Dallas and Director of the International Center for Decision and Risk Analysis which develops risk management research as it pertains to large-investment industrial projects that involve new technologies, applications and markets. He is also Chair Professor at City University Hong Kong.
Model based control has emerged as an important way to improve plant efficiency in the process industries, while meeting processing and operating policy constraints. The reader of Methods of Model Based Process Control will find state of the art reports on model based control technology presented by the world's leading scientists and experts from industry. All the important issues that a model based control system has to address are covered in depth, ranging from dynamic simulation and control-relevant identification to information integration. Specific emerging topics are also covered, such as robust control and nonlinear model predictive control. In addition to critical reviews of recent advances, the reader will find new ideas, industrial applications and views of future needs and challenges. Audience: A reference for graduate-level courses and a comprehensive guide for researchers and industrial control engineers in their exploration of the latest trends in the area.
Applied Optimal EstimationMIT Press
This text 1s designed to introduce the fundamentals of esti mation to engineers, scientists, and applied mathematicians. The level of the presentation should be accessible to senior under graduates and should prove especially well-suited as a self study guide for practicing professionals. My primary motivation for writing this book 1s to make a significant contribution toward minimizing the painful process most newcomers must go through in digesting and applying the theory. Thus the treatment 1s intro ductory and essence-oriented rather than comprehensive. While some original material 1s included, the justification for this text lies not in the contribution of dramatic new theoretical re sults, but rather in the degree of success I believe that I have achieved in providing a source from which this material may be learned more efficiently than through study of an existing text or the rather diffuse literature. This work is the outgrowth of the author's mid-1960's en counter with the subject while motivated by practical problems aSSociated with space vehicle orbit determination and estimation of powered rocket trajectories. The text has evolved as lecture notes for short courses and seminars given to professionals at Pr>efaae various private laboratories and government agencies, and during the past six years, in conjunction with engineering courses taught at the University of Virginia. To motivate the reader's thinking, the structure of a typical estimation problem often assumes the following form: • Given a dynamical system, a

mathematical model is hypothesized based upon the experience of the investigator.
Optimization, Estimation and Control
Estimation, Control, and the Discrete Kalman Filter
Inverse Methods for Atmospheric Sounding

Linear Quadratic Methods
A bottom-up approach that enables readers to master and apply the latest techniques in state estimation This book offers the best mathematical approaches to estimating the state of a general system. The author presents state estimation theory clearly and rigorously, providing the right amount of advanced material, recent research results, and references to enable the reader to apply state estimation techniques confidently across a variety of fields in science and engineering. While there are other textbooks that treat state estimation, this one offers special features and a unique perspective and pedagogical approach that speed learning: * Straightforward, bottom-up approach begins with basic concepts and then builds step by step to more advanced topics for a clear understanding of state estimation * Simple examples and problems that require only paper and pen to solve lead to an intuitive understanding of how theory works in practice * MATLAB(r)-based source code that corresponds to examples in the book, available on the author's Web site, enables readers to recreate results and experiment with other simulation setups and parameters Armed with a solid foundation in the basics, readers are presented with a careful treatment of advanced topics, including unscented filtering, high order nonlinear filtering, particle filtering, constrained state estimation, reduced order filtering, robust Kalman filtering, and mixed Kalman/H? filtering. Problems at the end of each chapter include both written exercises and computer exercises. Written exercises focus on improving the reader's understanding of theory and key concepts, whereas computer exercises help readers apply theory to problems similar to ones they are likely to encounter in industry. With its expert blend of theory and practice, coupled with its presentation of recent research results, Optimal State Estimation is strongly recommended for undergraduate and graduate-level courses in optimal control and state estimation theory. It also serves as a reference for engineers and science professionals across a wide array of industries.
This book covers optimal design for multi-input/multi-output (MIMO) systems, providing not only the theoretical background, but also practical implementation techniques for control and estimation algorithms. Real-time implementation methods for a wide range of industries and control problems are detailed, including control of computer disk drives, chemical process control, and aircraft control. The book puts modern control design tools - based on solving matrix equation - well within the reach of the individual design engineer. You'll see how to design control systems using software programs, simulate these controllers on digital controllers, and then implement digital controllers on actual processors using digital signal processors (DSPs). Appropriate
Optimal Estimation of Dynamic Systems, Second Edition highlights the importance of both physical and numerical modeling in solving dynamics-based estimation problems found in engineering systems. Accessible to engineering students, applied mathematicians, and practicing engineers, the text presents the central concepts and methods of optimal estimation theory and applies the methods to problems with varying degrees of analytical and numerical difficulty. Different approaches are often compared to show their absolute and relative utility. The authors also offer prototype algorithms to stimulate the development and proper use of efficient computer programs. MATLAB® codes for the examples are available on the book’s website. New to the Second Edition With more than 100 pages of new material, this reorganized edition expands upon the best-selling original to include comprehensive developments and updates. It incorporates new theoretical results, an entirely new chapter on advanced sequential state estimation, and additional examples and exercises. An ideal self-study guide for practicing engineers as well as senior undergraduate and beginning graduate students, the book introduces the fundamentals of estimation and helps newcomers to understand the relationships between the estimation and modeling of dynamical systems. It also illustrates the application of the theory to real-world situations, such as spacecraft attitude determination, GPS navigation, orbit determination, and aircraft tracking.
This unique text blends together state estimation and chemometrics for the application of advanced data-processing techniques. It further applies system theory in order to develop a modular framework to be implemented on computer for the development of simple intelligent analyzers. Short reviews on the history of state estimation and chemometrics are given, together with examples of the applications described, including classical estimation, state estimation, non-linear estimation, the multi-component, calibration and titration systems and the Kalman filter. The contents are very systematic and build the ideas up logically to appeal to specialist post-graduates working in this area, together with professionals in other areas of chemistry and engineering. Blends together state estimation and chemometrics for the application of advanced data-processing techniques Provides short reviews on the history of state estimation and chemometrics, together with examples of the applications described
Optimal Estimation of Dynamic Systems
Applied Optimal Control & Estimation
Optimization, Estimation, and Control
Optimal Control Theory
Optimal Estimation of Dynamic Systems, Second Edition
While the prediction of observations is a forward problem, the use of actual observations to infer the properties of a model is an inverse problem. Inverse problems are difficult because they may not have a unique solution. The description of uncertainties plays a central role in the theory, which is based on probability theory. This book proposes a general approach that is valid for linear as well as for nonlinear problems. The philosophy is essentially probabilistic and allows the reader to understand the basic difficulties appearing in the resolution of inverse problems. The book attempts to explain how a method of acquisition of information can be applied to actual real-world problems, and many of the arguments are heuristic.
Expert coverage of the design and implementation of stateestimation algorithms for tracking and navigation Estimation with Applications to Tracking and Navigationtreats the estimation of various quantities from inherentlyinaccurate remote observations. It explains state estimator designusing a balanced combination of linear systems, probability, andstatistics. The authors provide a review of the necessary backgroundmathematical techniques and offer an overview of the basic conceptsin estimation. They then provide detailed treatments of all themajor issues in estimation with a focus on applying thesetechniques to real systems. Other features include: Problems that apply theoretical material to real-worldapplications In-depth coverage of the Interacting Multiple Model (IMM)estimator Companion DynaEst(TM) software for MATLAB(TM) implementation ofKalman filters and IMM estimators Design guidelines for tracking filters Suitable for graduate engineering students and engineers workingin remote sensors and tracking, Estimation with Applications toTracking and Navigation provides expert coverage of thisimportant area.
Graduate-level text extends studies of signal processing, particularly regarding communication systems and digital filtering theory. Topics include filtering, linear systems, and estimation; discrete-time Kalman filter; time-invariant filters; more. 1979 edition.
A focused presentation of how sparse optimization methods can be used to solve optimal control and estimation problems.
An Introduction to the Theory for Parameter Estimation

State Estimation in Chemometrics
An Introduction to Optimal Estimation of Dynamical Systems
An introduction to optimal estimation
State Estimation and Optimal Control with Orthogonal Functions

Optimal control deals with the problem of finding a control law for a given system such that a certain optimality criterion is achieved. An optimal control is a set of differential equations describing the paths of the control variables that minimize the cost functional. This book, Continuous Time Dynamical Systems: State Estimation and Optimal Control with Orthogonal Functions, considers different classes of systems with quadratic performance criteria. It then attempts to find the optimal control law for each class of systems using orthogonal functions that can optimize the given performance criteria. Illustrated throughout with detailed examples, the book covers topics including: Block-pulse functions and shifted Legendre polynomials State estimation of linear time-invariant systems Linear optimal control systems incorporating observers Optimal control of systems described by integro-differential equations Linear-quadratic-Gaussian control Optimal control of singular systems Optimal control of time-delay systems with and without reverse time terms Optimal control of second-order nonlinear systems Hierarchical control of linear time-invariant and time-varying systems

A unified Bayesian treatment of the state-of-the-art filtering, smoothing, and parameter estimation algorithms for non-linear state space models.

This best-selling text focuses on the analysis and design of complicated dynamics systems. CHOICE called it ""a high-level, concise book that could well be used as a reference by engineers, applied mathematicians, and undergraduates. The format is good, the presentation clear, the diagrams instructive, the examples and problems helpful...References and a multiple-choice examination are included.

More than a decade ago, world-renowned control systems authority Frank L. Lewis introduced what would become a standard textbook on estimation, under the title Optimal Estimation, used in top universities throughout the world. The time has come for a new edition of this classic text, and Lewis enlisted the aid of two accomplished experts to bring the book completely up to date with the estimation methods driving today's high-performance systems. A Classic Revisited Optimal and Robust Estimation: With an Introduction to Stochastic Control Theory, Second Edition reflects new developments in estimation theory and design techniques. As the title suggests, the major feature of this edition is the inclusion of robust methods. Three new chapters cover the robust Kalman filter, H-infinity filtering, and H-infinity filtering of discrete-time systems. Modern Tools for Tomorrow's Engineers This text overflows with examples that highlight practical applications of the theory and concepts. Design algorithms appear conveniently in tables, allowing students quick reference, easy implementation into software, and intuitive comparisons for selecting the best algorithm for a given application. In addition, downloadable MATLAB® code allows students to gain hands-on experience with industry-standard software tools for a wide variety of applications. This cutting-edge and highly interactive text makes teaching, and learning, estimation methods easier and more modern than ever.

Kalman Filtering

Bayesian Filtering and Smoothing

With an Introduction to Stochastic Control Theory, Second Edition

An Introduction to Optimal Estimation

Digital Design & Implementation

A NEW EDITION OF THE CLASSIC TEXT ON OPTIMAL CONTROL THEORY As a superb introductory text and an indispensable reference, this new edition of Optimal Control will serve the needs of both the professional engineer and the advanced student in mechanical, electrical, and aerospace engineering. Its coverage encompasses all the fundamental topics as well as the major changes that have occurred in recent years. An abundance of computer simulations using MATLAB and relevant Toolboxes is included to give the reader the actual experience of applying the theory to real-world situations. Major topics covered include: Static Optimization Optimal Control of Discrete-Time Systems Optimal Control of Continuous-Time Systems The Tracking Problem and Other LQR Extensions Final-Time-Free and Constrained Input Control Dynamic Programming Optimal Control for Polynomial Systems Output Feedback and Structured Control Robustness and Multivariable Frequency-Domain Techniques Differential Games Reinforcement Learning and Optimal Adaptive Control

Most newcomers to the field of linear stochastic estimation go through a difficult process in understanding and applying the theory.This book minimizes the process while introducing the fundamentals of optimal estimation. Optimal Estimation of Dynamic Systems explores topics that are important in the field of control where the signals received are used to determine highly sensitive processes such as the flight path of a plane, the orbit of a space vehicle, or the control of a machine. The authors use dynamic models from mechanical and aerospace engineering to provide immediate results of estimation concepts with a minimal reliance on mathematical skills. The book documents the development of the central concepts and methods of optimal estimation theory in a manner accessible to engineering students, applied mathematicians, and practicing engineers. It includes rigorous theoretial derivations and a significant amount of qualitiative discussion and judgements. It also presents prototype algorithms, giving detail and discussion to stimulate development of efficient computer programs and intelligent use of them. This book illustrates the application of optimal estimation methods to problems with varying degrees of analytical and numercial difficulty. It compares various approaches to help develop a feel for the absolute and relative utility of different methods, and provides many applications in the fields of aerospace, mechanical, and electrical engineering.

Upper-level undergraduate text introduces aspects of optimal control theory: dynamic programming, Pontryagin's minimum principle, and numerical techniques for trajectory optimization. Numerous figures, tables. Solution guide available upon request. 1970 edition.

This best-selling text focuses on the analysis and design of complicated dynamics systems. CHOICE called it “a high-level, concise book that could well be used as a reference by engineers, applied mathematicians, and undergraduates. The format is good, the presentation clear, the diagrams instructive, the examples and problems helpful...References and a multiple-choice examination are included.”

Optimal Design
Continuous Time Dynamical Systems
Second Edition
Applied optimal estimation
Optimal Control and Estimation

Linear algebra; Nonlinear and linear dynamic systems; Elementary concepts of probability theory; Random dynamic systems; Lin estimation theory; Discrete dynamic system estimation; Continuous dynamic system estimation.

In this updated edition the main thrust is on applied Kalman filtering. Chapters 1-3 provide a minimal background in random process theory and the response of linear systems to random inputs. The following chapter is devoted to Wiener filtering and the remainder of the text deals with various facets of Kalman filtering with emphasis on applications. Starred problems at the end of each chapter are computer exercises. The authors believe that programming the equations and analyzing the results of specific examples is the best way to obtain the insight that is essential in engineering work.

Most newcomers to the field of linear stochastic estimation go through a difficult process in understanding and applying the theory.This book minimizes the process while introducing the fundamentals of optimal estimation. Optimal Estimation of Dynamic Systems explores topics that are important in the field of control where the signals receiv

This unified treatment presents material previously available only in journals, and in terms accessible to engineering students. Although theory is emphasized, it discusses numerous practical applications as well. 1970 edition.

Stochastic Processes and Filtering Theory

Theory and Practice with MATLAB

Methods and Applications with Deterministic Sample Points

Applied Optimal Estimation

An Engineering Approach to Optimal Control and Estimation Theory

The definitive textbook and professional reference on Kalman Filtering – fully updated, revised, and expanded This book contains the latest developments in the implementation and application of Kalman filtering. Authors Grewal and Andrews draw upon their decades of experience to offer an in-depth examination of the subtleties, common pitfalls, and limitations of estimation theory as it applies to real-world situations. They present many illustrative examples including adaptations for nonlinear filtering, global navigation satellite systems, the error modeling of gyros and accelerometers, inertial navigation systems, and freeway traffic control. Kalman Filtering: Theory and Practice Using MATLAB, Fourth Edition is an ideal textbook in advanced undergraduate and beginning graduate courses in stochastic processes and Kalman filtering. It is also appropriate for self-instruction or review by practicing engineers and scientists who want to learn more about this important topic.

This volume builds upon the foundations set in Volumes 1 and 2. Chapter 13 introduces the basic concepts of stochastic control and dynamic programming as the fundamental means of synthesizing optimal stochastic control laws.

In its highly organized overview of all areas, the book examines the design of modern optimal controllers requiring the selection of a performance criterion, demonstrates optimization of linear systems with bounded controls and limited control effort, and considers nonlinearities and their effect on various types of signals.

An Introduction
Kalman, H Infinity, and Nonlinear Approaches
Practical Methods for Optimal Control and Estimation Using Nonlinear Programming
Methods of Model Based Process Control
Inverse Problem Theory and Methods for Model Parameter Estimation