

Parameter Estimation and Inverse Problems

Second Edition

Richard C. Aster
Brian Borchers
Clifford H. Thurber

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Parameter Estimation And Inverse Problems

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Parameter Estimation and Inverse Problems Richard C. Aster, Brian Borchers, Clifford H. Thurber, 2018-10-16

Parameter Estimation and Inverse Problems Third Edition is structured around a course at New Mexico Tech and is designed to be accessible to typical graduate students in the physical sciences who do not have an extensive mathematical background. The book is complemented by a companion website that includes MATLAB codes that correspond to examples that are illustrated with simple easy to follow problems that illuminate the details of particular numerical methods. Updates to the new edition include more discussions of Laplacian smoothing, an expansion of basis function exercises, the addition of stochastic descent, an improved presentation of Fourier methods and exercises, and more. Features examples that are illustrated with simple easy to follow problems that illuminate the details of a particular numerical method. Includes an online instructor's guide that helps professors teach and customize exercises and select homework problems. Covers updated information on adjoint methods that are presented in an accessible manner.

Parameter Estimation and Inverse Problems Richard C. Aster, Clifford H. Thurber, Brian Borchers, 2005-01-11 Preface 1 Introduction 2 Linear Regression 3 Discretizing Continuous Inverse Problems 4 Rank Deficiency and Ill Conditioning 5 Tikhonov Regularization 6 Iterative Methods 7 Other Regularization Techniques 8 Fourier Techniques 9 Nonlinear Regression 10 Nonlinear Inverse Problems 11 Bayesian Methods Appendix A Review of Linear Algebra Appendix B Review of Probability and Statistics Appendix C Glossary of Notation Bibliography Index. Linear Regression Discretizing Continuous Inverse Problems Rank Deficiency and Ill Conditioning Tikhonov Regularization Iterative Methods Other Regularization Techniques Fourier Techniques Nonlinear Regression Nonlinear Inverse Problems Bayesian Methods

Parameter Estimation and Inverse Problems Richard C. Aster, Brian Borchers, Clifford H. Thurber, 2019 *Inverse Problem Theory and Methods for Model Parameter Estimation* Albert Tarantola, 2005-01-01 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.

Computational Methods for Inverse Problems Curtis R. Vogel, 2002-01-01 Provides a basic understanding of both the underlying mathematics and the computational methods used to solve inverse problems. Geophysical Inverse Theory Robert L. Parker, 2019-12-31 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

Numerical Methods for Inverse Problems Michel Kern, 2016-06-07 This book studies methods to concretely address inverse problems An inverse problem arises when the causes that produced a given effect must be determined or when one seeks to indirectly estimate the parameters of a physical system The author uses practical examples to illustrate inverse problems in physical sciences He presents the techniques and specific methods chosen to solve inverse problems in a general domain of application choosing to focus on a small number of methods that can be used in most applications This book is aimed at readers with a mathematical and scientific computing background Despite this it is a book with a practical perspective The methods described are applicable have been applied and are often illustrated by numerical examples

An Introduction to Data Analysis and Uncertainty Quantification for Inverse Problems Luis

Tenorio, 2017-07-06 Inverse problems are found in many applications such as medical imaging engineering astronomy and geophysics among others To solve an inverse problem is to recover an object from noisy usually indirect observations Solutions to inverse problems are subject to many potential sources of error introduced by approximate mathematical models regularization methods numerical approximations for efficient computations noisy data and limitations in the number of observations thus it is important to include an assessment of the uncertainties as part of the solution Such assessment is interdisciplinary by nature as it requires in addition to knowledge of the particular application methods from applied mathematics probability and statistics This book bridges applied mathematics and statistics by providing a basic introduction to probability and statistics for uncertainty quantification in the context of inverse problems as well as an introduction to statistical regularization of inverse problems The author covers basic statistical inference introduces the framework of ill posed inverse problems and explains statistical questions that arise in their applications An Introduction to Data Analysis and Uncertainty Quantification for Inverse Problems includes many examples that explain techniques which are useful to address general problems arising in uncertainty quantification Bayesian and non Bayesian statistical methods and discussions of their

complementary roles and analysis of a real data set to illustrate the methodology covered throughout the book Model Calibration and Parameter Estimation Ne-Zheng Sun, Alexander Sun, 2015-07-01 This three part book provides a comprehensive and systematic introduction to these challenging topics such as model calibration parameter estimation reliability assessment and data collection design Part 1 covers the classical inverse problem for parameter estimation in both deterministic and statistical frameworks Part 2 is dedicated to system identification hyperparameter estimation and model dimension reduction and Part 3 considers how to collect data and construct reliable models for prediction and decision making For the first time topics such as multiscale inversion stochastic field parameterization level set method machine learning global sensitivity analysis data assimilation model uncertainty quantification robust design and goal oriented modeling are systematically described and summarized in a single book from the perspective of model inversion and elucidated with numerical examples from environmental and water resources modeling Readers of this book will not only learn basic concepts and methods for simple parameter estimation but also get familiar with advanced methods for modeling complex systems Algorithms for mathematical tools used in this book such as numerical optimization automatic differentiation adaptive parameterization hierarchical Bayesian metamodeling Markov chain Monte Carlo are covered in details This book can be used as a reference for graduate and upper level undergraduate students majoring in environmental engineering hydrology and geosciences It also serves as an essential reference book for professionals such as petroleum engineers mining engineers chemists mechanical engineers biologists biology and medical engineering applied mathematicians and others who perform mathematical modeling **Algorithms for Optimization** Mykel J.

Kochenderfer, Tim A. Wheeler, 2019-03-12 A comprehensive introduction to optimization with a focus on practical algorithms for the design of engineering systems This book offers a comprehensive introduction to optimization with a focus on practical algorithms The book approaches optimization from an engineering perspective where the objective is to design a system that optimizes a set of metrics subject to constraints Readers will learn about computational approaches for a range of challenges including searching high dimensional spaces handling problems where there are multiple competing objectives and accommodating uncertainty in the metrics Figures examples and exercises convey the intuition behind the mathematical approaches The text provides concrete implementations in the Julia programming language Topics covered include derivatives and their generalization to multiple dimensions local descent and first and second order methods that inform local descent stochastic methods which introduce randomness into the optimization process linear constrained optimization when both the objective function and the constraints are linear surrogate models probabilistic surrogate models and using probabilistic surrogate models to guide optimization optimization under uncertainty uncertainty propagation expression optimization and multidisciplinary design optimization Appendixes offer an introduction to the Julia language test functions for evaluating algorithm performance and mathematical concepts used in the derivation and analysis of the optimization

methods discussed in the text The book can be used by advanced undergraduates and graduate students in mathematics statistics computer science any engineering field including electrical engineering and aerospace engineering and operations research and as a reference for professionals

Bayesian Approach to Inverse Problems Jérôme Idier, 2013-03-01 Many scientific medical or engineering problems raise the issue of recovering some physical quantities from indirect measurements for instance detecting or quantifying flaws or cracks within a material from acoustic or electromagnetic measurements at its surface is an essential problem of non destructive evaluation The concept of inverse problems precisely originates from the idea of inverting the laws of physics to recover a quantity of interest from measurable data Unfortunately most inverse problems are ill posed which means that precise and stable solutions are not easy to devise Regularization is the key concept to solve inverse problems The goal of this book is to deal with inverse problems and regularized solutions using the Bayesian statistical tools with a particular view to signal and image estimation The first three chapters bring the theoretical notions that make it possible to cast inverse problems within a mathematical framework The next three chapters address the fundamental inverse problem of deconvolution in a comprehensive manner Chapters 7 and 8 deal with advanced statistical questions linked to image estimation In the last five chapters the main tools introduced in the previous chapters are put into a practical context in important applicative areas such as astronomy or medical imaging

Inverse Problems in the Mathematical Sciences Charles W. Groetsch, 2013-12-14 Classical applied mathematics is dominated by the Laplacian paradigm of known causes evolving continuously into uniquely determined effects The classical direct problem is then to find the unique effect of a given cause by using the appropriate law of evolution It is therefore no surprise that traditional teaching in mathematics and the natural sciences emphasizes the point of view that problems have a solution this solution is unique and the solution is insensitive to small changes in the problem Such problems are called well posed and they typically arise from the so called direct problems of natural science The demands of science and technology have recently brought to the fore many problems that are inverse to the classical direct problems that is problems which may be interpreted as finding the cause of a given effect or finding the law of evolution given the cause and effect Included among such problems are many questions of remote sensing or indirect measurement such as the determination of internal characteristics of an inaccessible region from measurements on its boundary the determination of system parameters from input output measurements and the reconstruction of past events from measurements of the present state Inverse problems of this type are often ill posed in the sense that distinct causes can account for the same effect and small changes in a perceived effect can correspond to very large changes in a given cause Very frequently such inverse problems are modeled by integral equations of the first kind

Linear Algebra and Optimization for Machine Learning Charu C. Aggarwal, 2020-05-13 This textbook introduces linear algebra and optimization in the context of machine learning Examples and exercises are provided throughout the book A solution manual for the exercises at the end of each chapter is available to teaching instructors This textbook targets

graduate level students and professors in computer science mathematics and data science Advanced undergraduate students can also use this textbook The chapters for this textbook are organized as follows 1 Linear algebra and its applications The chapters focus on the basics of linear algebra together with their common applications to singular value decomposition matrix factorization similarity matrices kernel methods and graph analysis Numerous machine learning applications have been used as examples such as spectral clustering kernel based classification and outlier detection The tight integration of linear algebra methods with examples from machine learning differentiates this book from generic volumes on linear algebra The focus is clearly on the most relevant aspects of linear algebra for machine learning and to teach readers how to apply these concepts 2 Optimization and its applications Much of machine learning is posed as an optimization problem in which we try to maximize the accuracy of regression and classification models The parent problem of optimization centric machine learning is least squares regression Interestingly this problem arises in both linear algebra and optimization and is one of the key connecting problems of the two fields Least squares regression is also the starting point for support vector machines logistic regression and recommender systems Furthermore the methods for dimensionality reduction and matrix factorization also require the development of optimization methods A general view of optimization in computational graphs is discussed together with its applications to back propagation in neural networks A frequent challenge faced by beginners in machine learning is the extensive background required in linear algebra and optimization One problem is that the existing linear algebra and optimization courses are not specific to machine learning therefore one would typically have to complete more course material than is necessary to pick up machine learning Furthermore certain types of ideas and tricks from optimization and linear algebra recur more frequently in machine learning than other application centric settings Therefore there is significant value in developing a view of linear algebra and optimization that is better suited to the specific perspective of machine learning

Discrete Signals and Inverse Problems J. Carlos Santamarina,Dante Fratta,2005-12-13 Discrete Signals and Inverse Problems examines fundamental concepts necessary to engineers and scientists working with discrete signal processing and inverse problem solving and places emphasis on the clear understanding of algorithms within the context of application needs Based on the original Introduction to Discrete Signals and Inverse Problems in Civil Engineering this expanded and enriched version combines discrete signal processing and inverse problem solving in one book covers the most versatile tools that are needed to process engineering and scientific data presents step by step implementation procedures for the most relevant algorithms provides instructive figures solved examples and insightful exercises Discrete Signals and Inverse Problems is essential reading for experimental researchers and practicing engineers in civil mechanical and electrical engineering non destructive testing and instrumentation This book is also an excellent reference for advanced undergraduate students and graduate students in engineering and science

Groundwater Flow and Quality Modelling E. Custodio,A. Gurgui,J.P. Lobo Ferreira,1988-02-29 Proceedings of the NATO Advanced Research

Workshop on Advances in Analytical and Numerical Groundwater Flow and Quality Modelling Lisbon Portugal June 2 6 1987

Large-Scale Inverse Problems and Quantification of Uncertainty Lorenz Biegler, George Biros, Omar Ghattas, Matthias Heinkenschloss, David Keyes, Bani Mallick, Luis Tenorio, Bart van Bloemen Waanders, Karen Willcox, Youssef Marzouk, 2011-06-24 This book focuses on computational methods for large scale statistical inverse problems and provides an introduction to statistical Bayesian and frequentist methodologies Recent research advances for approximation methods are discussed along with Kalman filtering methods and optimization based approaches to solving inverse problems The aim is to cross fertilize the perspectives of researchers in the areas of data assimilation statistics large scale optimization applied and computational mathematics high performance computing and cutting edge applications The solution to large scale inverse problems critically depends on methods to reduce computational cost Recent research approaches tackle this challenge in a variety of different ways Many of the computational frameworks highlighted in this book build upon state of the art methods for simulation of the forward problem such as fast Partial Differential Equation PDE solvers reduced order models and emulators of the forward problem stochastic spectral approximations and ensemble based approximations as well as exploiting the machinery for large scale deterministic optimization through adjoint and other sensitivity analysis methods Key Features Brings together the perspectives of researchers in areas of inverse problems and data assimilation Assesses the current state of the art and identify needs and opportunities for future research Focuses on the computational methods used to analyze and simulate inverse problems Written by leading experts of inverse problems and uncertainty quantification Graduate students and researchers working in statistics mathematics and engineering will benefit from this book

Numerical Methods for Solving Inverse Problems of Mathematical Physics A. A. Samarskii, Petr N. Vabishchevich, 2008-08-27 The main classes of inverse problems for equations of mathematical physics and their numerical solution methods are considered in this book which is intended for graduate students and experts in applied mathematics computational mathematics and mathematical modelling **Iterative Optimization in Inverse Problems** Charles Byrne, 2014-02-12 Iterative Optimization in Inverse Problems brings together a number of important iterative algorithms for medical imaging optimization and statistical estimation It incorporates recent work that has not appeared in other books and draws on the author's considerable research in the field including his recently developed class of SUMMA algorithms

Modeling and Inverse Problems in Imaging Analysis Bernard Chalmond, 2003-01-14 More mathematicians have been taking part in the development of digital image processing as a science and the contributions are reflected in the increasingly important role modeling has played solving complex problems This book is mostly concerned with energy based models Most of these models come from industrial projects in which the author was involved in robot vision and radiography tracking 3D lines radiographic image processing 3D reconstruction and tomography matching deformation learning Numerous graphical illustrations accompany the text

Embracing the Tune of Appearance: An Mental Symphony within **Parameter Estimation And Inverse Problems**

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