Mathematics and its Applications

Heinz W. Engl, Martin Hanke and Andreas Neubauer

Regularization of Inverse Problems



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<u>Regularization Of Inverse Problems</u>

Thomas Schuster,Barbara Kaltenbacher,Bernd Hofmann,Kamil S. Kazimierski

Regularization Of Inverse Problems:

Regularization of Inverse Problems Heinz Werner Engl, Martin Hanke, A. Neubauer, 2000-03-31 This book is devoted to the mathematical theory of regularization methods and gives an account of the currently available results about regularization methods for linear and nonlinear ill posed problems Both continuous and iterative regularization methods are considered in detail with special emphasis on the development of parameter choice and stopping rules which lead to optimal Computational Methods for Inverse Problems Curtis R. Vogel, 2002-01-01 Provides a basic convergence rates understanding of both the underlying mathematics and the computational methods used to solve inverse problems Α Taste of Inverse Problems Martin Hanke, 2017-01-01 Inverse problems need to be solved in order to properly interpret indirect measurements Often inverse problems are ill posed and sensitive to data errors Therefore one has to incorporate some sort of regularization to reconstruct significant information from the given data This book presents the main achievements that have emerged in regularization theory over the past 50 years focusing on linear ill posed problems and the development of methods that can be applied to them Some of this material has previously appeared only in journal articles A Taste of Inverse Problems Basic Theory and Examples rigorously discusses state of the art inverse problems theory focusing on numerically relevant aspects and omitting subordinate generalizations presents diverse real world applications important test cases and possible pitfalls and treats these applications with the same rigor and depth as the theory Numerical Regularization for Atmospheric Inverse Problems Adrian Doicu, Thomas Trautmann, Franz Schreier, 2014-10-31 The retrieval problems arising in atmospheric remote sensing belong to the class of the called discrete ill posed problems These problems are unstable under data perturbations and can be solved by numerical regularization methods in which the solution is stabilized by taking additional information into account The goal of this research monograph is to present and analyze numerical algorithms for atmospheric retrieval The book is aimed at physicists and engineers with some ba ground in numerical linear algebra and matrix computations Although there are many practical details in this book for a robust and ef cient implementation of all numerical algorithms the reader should consult the literature cited The data model adopted in our analysis is semi stochastic From a practical point of view there are no signi cant differences between a semi stochastic and a determin tic framework the differences are relevant from a theoretical point of view e g in the convergence and convergence rates analysis After an introductory chapter providing the state of the art in passive atmospheric remote sensing Chapter 2 introduces the concept of ill posedness for linear discrete eq tions To illustrate the dif culties associated with the solution of discrete ill posed pr lems we consider the temperature retrieval by nadir sounding and analyze the solvability of the discrete equation by using the singular value decomposition of the forward model matrix An Introduction to the Mathematical Theory of Inverse Problems Andreas Kirsch, 2011-03-24 This book introduces the reader to the area of inverse problems The study of inverse problems is of vital interest to many areas of science and technology such as geophysical exploration system

identification nondestructive testing and ultrasonic tomography The aim of this book is twofold in the first part the reader is exposed to the basic notions and difficulties encountered with ill posed problems Basic properties of regularization methods for linear ill posed problems are studied by means of several simple analytical and numerical examples. The second part of the book presents two special nonlinear inverse problems in detail the inverse spectral problem and the inverse scattering problem The corresponding direct problems are studied with respect to existence uniqueness and continuous dependence on parameters Then some theoretical results as well as numerical procedures for the inverse problems are discussed The choice of material and its presentation in the book are new thus making it particularly suitable for graduate students Basic knowledge of real analysis is assumed In this new edition the Factorization Method is included as one of the prominent members in this monograph Since the Factorization Method is particularly simple for the problem of EIT and this field has attracted a lot of attention during the past decade a chapter on EIT has been added in this monograph as Chapter 5 while the chapter on inverse scattering theory is now Chapter 6 The main changes of this second edition compared to the first edition concern only Chapters 5 and 6 and the Appendix A Chapter 5 introduces the reader to the inverse problem of electrical impedance tomography Linear and Nonlinear Inverse Problems with Practical Applications Jennifer L. Mueller, Samuli Siltanen, 2012-11-30 Inverse problems arise in practical applications whenever there is a need to interpret indirect measurements This book explains how to identify ill posed inverse problems arising in practice and gives a hands on guide to designing computational solution methods for them with related codes on an accompanying website The guiding linear inversion examples are the problem of image deblurring x ray tomography and backward parabolic problems including heat transfer A thorough treatment of electrical impedance tomography is used as the guiding nonlinear inversion example which combines the analytic geometric research tradition and the regularization based school of thought in a fruitful manner This book is complete with exercises and project topics making it ideal as a classroom textbook or self study guide for graduate and advanced undergraduate students in mathematics engineering or physics who wish to learn about computational inversion It also acts as a useful guide for researchers who develop inversion techniques in high tech industry

<u>Parameter Estimation and Inverse Problems</u> 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 Inverse Problems Mathias Richter, 2016-11-24 The overall goal of the book is to provide access to the regularized solution of inverse problems relevant in geophysics without requiring more mathematical knowledge than is taught in undergraduate math courses for scientists and engineers From abstract analysis only the concept of functions as vectors is needed Function spaces are introduced informally in the course of the text when needed Additionally a more detailed but still condensed introduction is given in Appendix B A second goal is to elaborate the single steps to be taken when solving an inverse problem discretization regularization and practical solution of the regularized optimization problem These steps are shown in detail for model problems from the fields of inverse gravimetry and seismic tomography The intended audience is mathematicians physicists and engineers having a good working knowledge of linear algebra and analysis at the upper undergraduate level **Regularization Algorithms for Ill-Posed** Problems Anatoly B. Bakushinsky, Mikhail M. Kokurin, Mikhail Yu. Kokurin, 2018-02-05 This specialized and authoritative book contains an overview of modern approaches to constructing approximations to solutions of ill posed operator equations both linear and nonlinear These approximation schemes form a basis for implementable numerical algorithms for the stable solution of operator equations arising in contemporary mathematical modeling and in particular when solving inverse problems of mathematical physics The book presents in detail stable solution methods for ill posed problems using the methodology of iterative regularization of classical iterative schemes and the techniques of finite dimensional and finite difference approximations of the problems under study Special attention is paid to ill posed Cauchy problems for linear operator differential equations and to ill posed variational inequalities and optimization problems The readers are expected to have basic knowledge in functional analysis and differential equations The book will be of interest to applied mathematicians and specialists in mathematical modeling and inverse problems and also to advanced students in these fields Contents Introduction Regularization Methods For Linear Equations Finite Difference Methods Iterative Regularization Methods Finite Dimensional Iterative Processes Variational Inequalities and Optimization Problems Regularization Methods in Banach Spaces Thomas Schuster, Barbara Kaltenbacher, Bernd Hofmann, Kamil S. Kazimierski, 2012-07-30 Regularization methods aimed at finding stable approximate solutions are a necessary tool to tackle inverse and ill posed problems Inverse problems arise in a large variety of applications ranging from medical imaging and non destructive testing via finance to systems biology Many of these problems belong to the class of parameter identification problems in partial differential equations PDEs and thus are computationally demanding and mathematically challenging Hence there is a substantial need for stable and efficient solvers for this kind of problems as well as for a rigorous convergence analysis of these methods This monograph consists of five parts Part I motivates the importance of developing and analyzing regularization methods in Banach spaces by presenting four applications which intrinsically demand for a Banach space

setting and giving a brief glimpse of sparsity constraints Part II summarizes all mathematical tools that are necessary to carry out an analysis in Banach spaces Part III represents the current state of the art concerning Tikhonov regularization in Banach spaces Part IV about iterative regularization methods is concerned with linear operator equations and the iterative solution of nonlinear operator equations by gradient type methods and the iteratively regularized Gau Newton method Part V finally outlines the method of approximate inverse which is based on the efficient evaluation of the measured data with Iterative Regularization Methods for Nonlinear Ill-posed Problems Barbara reconstruction kernels Kaltenbacher, Andreas Neubauer, Otmar Scherzer, 2008 The series is devoted to the publication of high level monographs surveys and proceedings which cover the whole spectrum of computational and applied mathematics The books of this series are addressed to both specialists and advanced students Interested authors may submit book proposals to the Managing Editor or to any member of the Editorial Board Managing Editor Ulrich Langer Johannes Kepler University Linz Austria Editorial Board Hansj rg Albrecher University of Lausanne Switzerland Ronald H W Hoppe University of Houston USA Karl Kunisch RICAM Linz Austria University of Graz Austria Harald Niederreiter RICAM Linz Austria Christian Schmeiser University of Vienna Austria 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 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 Inverse Problems in Engineering Mechanics Masataka Tanaka, Huy D. Bui, 2013-03-08 Inverse problems occur in a wide variey of fields In general the inverse problem can be defined as one where one should estimate the cause from the result while the direct problem is concerned with how to obtain the result from the cause The aim of this symposium was to gather scientists and researchers in engineering mechanics concerned with inverse problems in order to exchange research result and develop computational and experimental approaches to solve inverse problems The contributions in this volume cover the following subjects mathematical and computational aspects of inverse problems parameter or system identification shape determination sensitivity analysis optimization material property characterization ultrasonic nondestructive testing elastodynamic inverse problems thermal inverse problems and other miscellaneous engineering applications **Introduction to Inverse Problems in Imaging** M. Bertero, P. Boccacci, 2020-08-30 This is a graduate textbook on the principles of linear inverse problems methods of their approximate solution and practical application in imaging The level of mathematical treatment is kept as low as possible to make the book suitable for a wide range of readers from different backgrounds in science and engineering Mathematical prerequisites are first courses in analysis geometry linear algebra probability theory and Fourier analysis The authors concentrate on presenting easily implementable and fast solution algorithms With examples and exercises throughout the book will provide the reader with the appropriate background for a clear understanding of the essence of inverse problems ill posedness and its cure and consequently for an intelligent assessment of the rapidly growing literature on these problems Inverse Problems and Related Topics Jin Cheng, Shuai Lu, Masahiro Yamamoto, 2020-02-04 This volume contains 13 chapters which are extended versions of the presentations at International Conference on Inverse Problems at Fudan University Shanghai China October 12 14 2018 in honor of Masahiro Yamamoto on the occasion of his 60th anniversary The chapters are authored by world renowned researchers and rising young talents and are updated accounts of various aspects of the researches on inverse problems The volume covers theories of inverse problems for partial differential equations regularization methods and related topics from control theory This book addresses a wide audience of researchers and young post docs and graduate students who are interested in mathematical sciences as well as mathematics

Inverse and Ill-posed Problems Sergey I. Kabanikhin, 2011-12-23 The theory of ill posed problems originated in an unusual way As a rule a new concept is a subject in which its creator takes a keen interest The concept of ill posed problems was introduced by Hadamard with the comment that these problems are physically meaningless and not worthy of the attention of serious researchers Despite Hadamard s pessimistic forecasts however his unloved child has turned into a powerful theory whose results are used in many fields of pure and applied mathematics What is the secret of its success The answer is clear Ill posed problems occur everywhere and it is unreasonable to ignore them Unlike ill posed problems inverse problems have no strict mathematical definition In general they can be described as the task of recovering a part of the data of a corresponding direct well posed problem from information about its solution Inverse problems were first encountered in practice and are mostly ill posed The urgent need for their solution especially in geological exploration and medical diagnostics has given powerful impetus to the development of the theory of ill posed problems Nowadays the terms inverse problem and ill posed problem are inextricably linked to each other Inverse and ill posed problems are currently attracting great interest A vast literature is devoted to these problems making it necessary to systematize the accumulated material This book is the first small step in that direction We propose a classification of inverse problems according to the type of equation unknowns and additional information We consider specific problems from a single position and indicate relationships between them The problems relate to different areas of mathematics such as linear algebra theory of integral equations integral geometry spectral theory and mathematical physics We give examples of applied problems that can be studied using the techniques we describe This book was conceived as a textbook on the foundations of the theory of inverse and ill posed problems for university students The author s intention was to explain this complex material in the most accessible way possible The monograph is aimed primarily at those who are just beginning to get to grips with inverse and ill posed problems but we hope that it will be useful to anyone who is interested in the subject Comprehensive Electrocardiology Peter W. Macfarlane, Adriaan van Oosterom, Olle Pahlm, Paul Kligfield, Michiel Janse, John Camm, 2010-11-05 New edition of the classic complete reference book for cardiologists and trainee cardiologists on the theory and practice of electrocardiography one of the key modalities used for evaluating cardiology patients and deciding on appropriate

management strategies **Regularization of Inverse Problems** Heinz Werner Engl, Martin Hanke, A.

Neubauer,2000-04-14 This book is devoted to the mathematical theory of regularization methods and gives an account of the currently available results about regularization methods for linear and nonlinear ill posed problems Both continuous and iterative regularization methods are considered in detail with special emphasis on the development of parameter choice and stopping rules which lead to optimal convergence rates

Adopting the Track of Expression: An Psychological Symphony within Regularization Of Inverse Problems

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