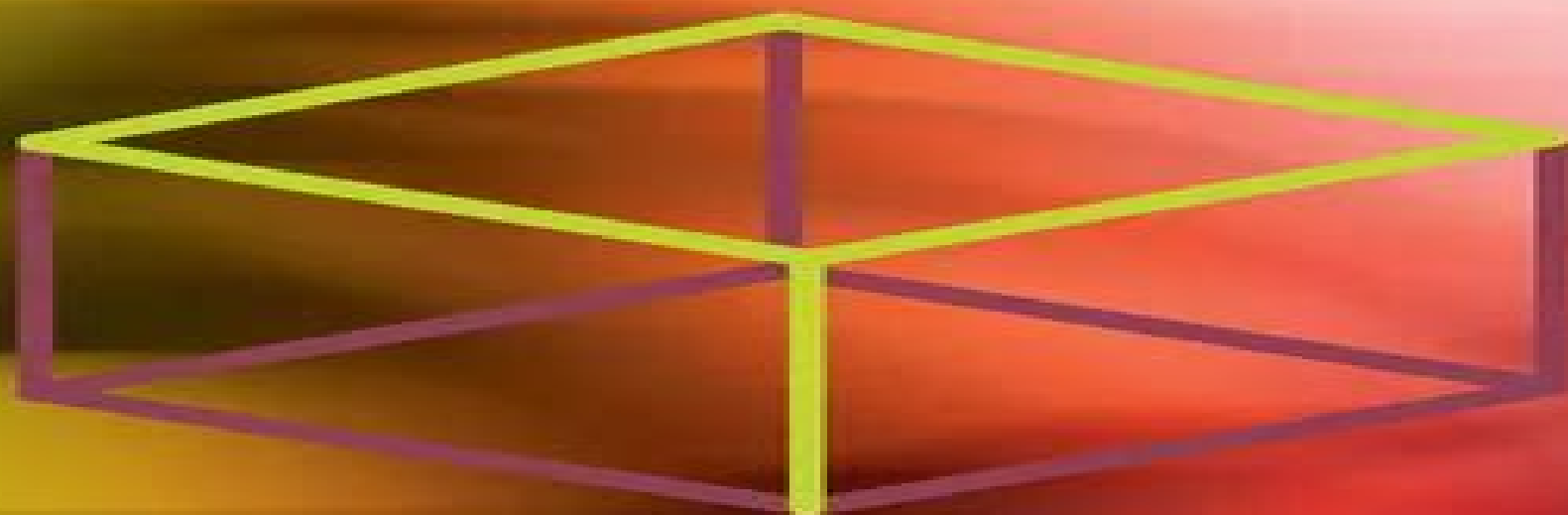


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LARGE-SCALE INVERSE PROBLEMS AND QUANTIFICATION OF UNCERTAINTY

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Large Scale Inverse Problems And Quantification Of Uncertainty

**Stephen Ekwaro-Osire, Aparecido
Carlos Gonçalves, Fisseha M.
Alemayehu**

Large Scale Inverse Problems And Quantification Of Uncertainty:

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, 2010-10-12 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

Bayesian Uncertainty Quantification for Large Scale Spatial Inverse Problems Anirban Mondal, 2012 We considered a Bayesian approach to nonlinear inverse problems in which the unknown quantity is a high dimension spatial field The Bayesian approach contains a natural mechanism for regularization in the form of prior information can incorporate information from heterogeneous sources and provides a quantitative assessment of uncertainty in the inverse solution The Bayesian setting casts the inverse solution as a posterior probability distribution over the model parameters Karhunen Lo eve expansion and Discrete Cosine transform were used for dimension reduction of the random spatial field Furthermore we used a hierarchical Bayes model to inject multiscale data in the modeling framework In this Bayesian framework we have shown that this inverse problem is well posed by proving that the posterior measure is Lipschitz continuous with respect to the data in total variation norm The need for multiple evaluations of the forward model on a high dimension spatial field e g in the context of MCMC together with the high dimensionality of the posterior results in many computation challenges We developed two stage reversible jump MCMC method which has the ability to screen the bad proposals in the first inexpensive stage Channelized spatial fields were represented by facies boundaries and variogram based spatial fields within each facies Using level set based approach the shape of the channel boundaries was updated with dynamic data using a Bayesian

hierarchical model where the number of points representing the channel boundaries is assumed to be unknown. Statistical emulators on a large scale spatial field were introduced to avoid the expensive likelihood calculation which contains the forward simulator at each iteration of the MCMC step. To build the emulator the original spatial field was represented by a low dimensional parameterization using Discrete Cosine Transform (DCT). Then the Bayesian approach to multivariate adaptive regression spline (BMARS) was used to emulate the simulator. Various numerical results were presented by analyzing simulated as well as real data. *Handbook of Dynamic Data Driven Applications Systems* Frederica Darema, Erik P. Blasch, Sai Ravela, Alex J. Aved, 2023-09-14. This Second Volume in the series *Handbook of Dynamic Data Driven Applications Systems* (DDDAS) expands the scope of the methods and the application areas presented in the first Volume and aims to provide additional and extended content of the increasing set of science and engineering advances for new capabilities enabled through DDDAS. The methods and examples of breakthroughs presented in the book series capture the DDDAS paradigm and its scientific and technological impact and benefits. The DDDAS paradigm and the ensuing DDDAS based frameworks for systems analysis and design have been shown to engender new and advanced capabilities for understanding analysis and management of engineered natural and societal systems applications systems and for the commensurate wide set of scientific and engineering fields and applications as well as foundational areas. The DDDAS book series aims to be a reference source of many of the important research and development efforts conducted under the rubric of DDDAS and to also inspire the broader communities of researchers and developers about the potential in their respective areas of interest of the application and the exploitation of the DDDAS paradigm and the ensuing frameworks through the examples and case studies presented either within their own field or other fields of study. As in the first volume the chapters in this book reflect research work conducted over the years starting in the 1990s to the present. Here the theory and application content are considered for Foundational Methods Materials Systems Structural Systems Energy Systems Environmental Systems Domain Assessment address challenges that ML alone does not and also show how ML in combination with DDDAS based methods can deliver the advanced capabilities sought likewise infusion of DDDAS like approaches in NN methods strengthens such methods. Moreover the DDDAS based Digital Twin or Dynamic Digital Twin goes beyond the traditional DT notion where the model and the physical system are viewed side by side in a static way to a paradigm where the model dynamically interacts with the physical system through its instrumentation per the DDDAS feed back control loop between model and instrumentation. *Recent Numerical Advances in Fluid Mechanics* Omer San, 2020-07-03. In recent decades the field of computational fluid dynamics has made significant advances in enabling advanced computing architectures to understand many phenomena in biological geophysical and engineering fluid flows. Almost all research areas in fluids use numerical methods at various complexities from molecular to continuum descriptions from laminar to turbulent regimes from low speed to hypersonic from stencil based computations to meshless approaches from local basis functions to global expansions as well

as from first order approximation to high order with spectral accuracy Many successful efforts have been put forth in dynamic adaptation strategies e g adaptive mesh refinement and multiresolution representation approaches Furthermore with recent advances in artificial intelligence and heterogeneous computing the broader fluids community has gained the momentum to revisit and investigate such practices This Special Issue containing a collection of 13 papers brings together researchers to address recent numerical advances in fluid mechanics Monte Carlo and Quasi-Monte Carlo Methods 2010 Leszek Plaskota, Henryk Woźniakowski, 2012-08-23 This book represents the refereed proceedings of the Ninth International Conference on Monte Carlo and Quasi Monte Carlo Methods in Scientific Computing that was held at the University of Warsaw Poland in August 2010 These biennial conferences are major events for Monte Carlo and the premiere event for quasi Monte Carlo research The proceedings include articles based on invited lectures as well as carefully selected contributed papers on all theoretical aspects and applications of Monte Carlo and quasi Monte Carlo methods The reader will be provided with information on latest developments in these very active areas The book is an excellent reference for theoreticians and practitioners interested in solving high dimensional computational problems arising in particular in finance and statistics **Grand Challenges in Earthquake Engineering Research** National Research Council, Division on Earth and Life Studies, Board on Earth Sciences and Resources, Committee on Seismology and Geodynamics, Committee for the Workshop on Grand Challenges in Earthquake Engineering Research—"A Vision for NEES Experimental Facilities and Cyberinfrastructure Tools, 2011-10-30 As geological threats become more imminent society must make a major commitment to increase the resilience of its communities infrastructure and citizens Recent earthquakes in Japan New Zealand Haiti and Chile provide stark reminders of the devastating impact major earthquakes have on the lives and economic stability of millions of people worldwide The events in Haiti continue to show that poor planning and governance lead to long term chaos while nations like Chile demonstrate steady recovery due to modern earthquake planning and proper construction and mitigation activities At the request of the National Science Foundation the National Research Council hosted a two day workshop to give members of the community an opportunity to identify Grand Challenges for earthquake engineering research that are needed to achieve an earthquake resilient society as well as to describe networks of earthquake engineering experimental capabilities and cyberinfrastructure tools that could continue to address ongoing areas of concern Grand Challenges in Earthquake Engineering Research A Community Workshop Report explores the priorities and problems regions face in reducing consequent damage and spurring technological preparedness advances Over the course of the Grand Challenges in Earthquake Engineering Research workshop 13 grand challenge problems emerged and were summarized in terms of five overarching themes including community resilience framework decision making simulation mitigation and design tools Participants suggested 14 experimental facilities and cyberinfrastructure tools that would be needed to carry out testing observations and simulations and to analyze the results The report also reviews progressive steps

that have been made in research and development and considers what factors will accelerate transformative solutions

Numerical Analysis and Optimization Mehiddin Al-Baali, Lucio Grandinetti, Anton Purnama, 2015-07-16 Presenting the latest findings in the field of numerical analysis and optimization this volume balances pure research with practical applications of the subject Accompanied by detailed tables figures and examinations of useful software tools this volume will equip the reader to perform detailed and layered analysis of complex datasets Many real world complex problems can be formulated as optimization tasks Such problems can be characterized as large scale unconstrained constrained non convex non differentiable and discontinuous and therefore require adequate computational methods algorithms and software tools These same tools are often employed by researchers working in current IT hot topics such as big data optimization and other complex numerical algorithms on the cloud devising special techniques for supercomputing systems The list of topics covered include but are not limited to numerical analysis numerical optimization numerical linear algebra numerical differential equations optimal control approximation theory applied mathematics algorithms and software developments derivative free optimization methods and programming models The volume also examines challenging applications to various types of computational optimization methods which usually occur in statistics econometrics finance physics medicine biology engineering and industrial sciences

Inverse Problems and Data Assimilation Daniel Sanz-Alonso, Andrew Stuart, Armeen Taeb, 2023-08-10 This concise introduction provides an entry point to the world of inverse problems and data assimilation for advanced undergraduates and beginning graduate students in the mathematical sciences It will also appeal to researchers in science and engineering who are interested in the systematic underpinnings of methodologies widely used in their disciplines The authors examine inverse problems and data assimilation in turn before exploring the use of data assimilation methods to solve generic inverse problems by introducing an artificial algorithmic time Topics covered include maximum a posteriori estimation stochastic gradient descent variational Bayes Monte Carlo importance sampling and Markov chain Monte Carlo for inverse problems and 3DVAR 4DVAR extended and ensemble Kalman filters and particle filters for data assimilation The book contains a wealth of examples and exercises and can be used to accompany courses as well as for self study

Advanced Methods for Processing and Visualizing the Renewable Energy Samsul Ariffin Abdul Karim, Nordin Saad, Ramani Kannan, 2020-10-21 This book is a collection of research work conducted by researchers at Centre for Smart Grid Energy Research CSMER Institute of Autonomous System Universiti Teknologi PETRONAS UTP and Seismic Modelling and Inversion Group King Abdullah University of Science and Technology KAUST Saudi Arabia The book covers topics in the field of renewable energy where visualization artificial neural network and deep learning techniques have been applied to optimize the performance of various applications in energy related industries These examples include a natural gas vehicle NGV a single axis and a fixed axis solar tracker seismic inversion enhanced oil recovery viability of a PV system and construction of a septic B spline tensor product scheme Readers will benefit from these examples which describe

the current trend of energy optimization techniques in renewable energy applications making it a good reference for the researchers and industrial practitioners working in the field of renewable energy and optimization techniques

Deterministic and Stochastic Optimal Control and Inverse Problems Baasansuren Jadamba, Akhtar A. Khan, Stanisław Migórski, Miguel Sama, 2021-12-14 Inverse problems of identifying parameters and initial boundary conditions in deterministic and stochastic partial differential equations constitute a vibrant and emerging research area that has found numerous applications A related problem of paramount importance is the optimal control problem for stochastic differential equations This edited volume comprises invited contributions from world renowned researchers in the subject of control and inverse problems There are several contributions on optimal control and inverse problems covering different aspects of the theory numerical methods and applications Besides a unified presentation of the most recent and relevant developments this volume also presents some survey articles to make the material self contained To maintain the highest level of scientific quality all manuscripts have been thoroughly reviewed

Mesoscale Modeling in Chemical Engineering Part I

,2015-11-26 Focusing Mesoscales of Multiscale Problems in Chemical Engineering a volume in the Advances in Chemical Engineering series provides readers with the personal views of recognized authorities who present assessments of the state of the art in the field and help readers develop an understanding of its further evolution Subjects covered in the book are not limited to the classical chemical engineering disciplines Contributions connecting chemical engineering to related scientific fields either providing a fundamental basis or introducing new concepts and tools are encouraged This volume aims to create a balance between well developed areas such as process industry transformation of materials energy and environmental issues and areas where applications of chemical engineering are more recent or emerging Contains reviews by leading authorities in their respective areas Provides up to date reviews of the latest techniques in the modeling of catalytic processes Includes a broad mix of US and European authors as well as academic industrial research institute perspectives Provides discussions on the connections between computation and experimental methods

Probabilistic Prognostics and Health Management of Energy Systems Stephen Ekwaro-Osire, Aparecido Carlos Gonçalves, Fisseha M.

Alemayehu, 2017-04-25 This book proposes the formulation of an efficient methodology that estimates energy system uncertainty and predicts Remaining Useful Life RUL accurately with significantly reduced RUL prediction uncertainty Renewable and non renewable sources of energy are being used to supply the demands of societies worldwide These sources are mainly thermo chemo electro mechanical systems that are subject to uncertainty in future loading conditions material properties process noise and other design parameters It book informs the reader of existing and new ideas that will be implemented in RUL prediction of energy systems in the future The book provides case studies illustrations graphs and charts Its chapters consider engineering reliability prognostics and health management probabilistic multibody dynamical analysis peridynamic and finite element modelling computer science and mathematics

Knowledge Guided Machine

Learning Anuj Karpatne, Ramakrishnan Kannan, Vipin Kumar, 2022-08-15 Given their tremendous success in commercial applications machine learning ML models are increasingly being considered as alternatives to science based models in many disciplines Yet these black box ML models have found limited success due to their inability to work well in the presence of limited training data and generalize to unseen scenarios As a result there is a growing interest in the scientific community on creating a new generation of methods that integrate scientific knowledge in ML frameworks This emerging field called scientific knowledge guided ML KGML seeks a distinct departure from existing data only or scientific knowledge only methods to use knowledge and data at an equal footing Indeed KGML involves diverse scientific and ML communities where researchers and practitioners from various backgrounds and application domains are continually adding richness to the problem formulations and research methods in this emerging field Knowledge Guided Machine Learning Accelerating Discovery using Scientific Knowledge and Data provides an introduction to this rapidly growing field by discussing some of the common themes of research in KGML using illustrative examples case studies and reviews from diverse application domains and research communities as book chapters by leading researchers KEY FEATURES First of its kind book in an emerging area of research that is gaining widespread attention in the scientific and data science fields Accessible to a broad audience in data science and scientific and engineering fields Provides a coherent organizational structure to the problem formulations and research methods in the emerging field of KGML using illustrative examples from diverse application domains Contains chapters by leading researchers which illustrate the cutting edge research trends opportunities and challenges in KGML research from multiple perspectives Enables cross pollination of KGML problem formulations and research methods across disciplines Highlights critical gaps that require further investigation by the broader community of researchers and practitioners to realize the full potential of KGML

Extraction of Quantifiable Information from Complex Systems Stephan Dahlke, Wolfgang Dahmen, Michael Griebel, Wolfgang Hackbusch, Klaus Ritter, Reinhold Schneider, Christoph Schwab, Harry Yserentant, 2014-11-13 In April 2007 the Deutsche Forschungsgemeinschaft DFG approved the Priority Program 1324 Mathematical Methods for Extracting Quantifiable Information from Complex Systems This volume presents a comprehensive overview of the most important results obtained over the course of the program Mathematical models of complex systems provide the foundation for further technological developments in science engineering and computational finance Motivated by the trend toward steadily increasing computer power ever more realistic models have been developed in recent years These models have also become increasingly complex and their numerical treatment poses serious challenges Recent developments in mathematics suggest that in the long run much more powerful numerical solution strategies could be derived if the interconnections between the different fields of research were systematically exploited at a conceptual level Accordingly a deeper understanding of the mathematical foundations as well as the development of new and efficient numerical algorithms were among the main goals of this Priority Program The

treatment of high dimensional systems is clearly one of the most challenging tasks in applied mathematics today Since the problem of high dimensionality appears in many fields of application the above mentioned synergy and cross fertilization effects were expected to make a great impact To be truly successful the following issues had to be kept in mind theoretical research and practical applications had to be developed hand in hand moreover it has proven necessary to combine different fields of mathematics such as numerical analysis and computational stochastics To keep the whole program sufficiently focused we concentrated on specific but related fields of application that share common characteristics and as such they allowed us to use closely related approaches

Sparse Grids and Applications - Stuttgart 2014 Jochen Garcke, Dirk Pflüger, 2016-03-16 This volume of LNCSE is a collection of the papers from the proceedings of the third workshop on sparse grids and applications Sparse grids are a popular approach for the numerical treatment of high dimensional problems Where classical numerical discretization schemes fail in more than three or four dimensions sparse grids in their different guises are frequently the method of choice be it spatially adaptive in the hierarchical basis or via the dimensionally adaptive combination technique Demonstrating once again the importance of this numerical discretization scheme the selected articles present recent advances on the numerical analysis of sparse grids as well as efficient data structures The book also discusses a range of applications including uncertainty quantification and plasma physics

Variational Methods Maitine Bergounioux, Gabriel Peyré, Christoph Schnörr, Jean-Baptiste Caillaud, Thomas Haberkorn, 2017-01-11 With a focus on the interplay between mathematics and applications of imaging the first part covers topics from optimization inverse problems and shape spaces to computer vision and computational anatomy The second part is geared towards geometric control and related topics including Riemannian geometry celestial mechanics and quantum control Contents Part I Second order decomposition model for image processing numerical experimentation Optimizing spatial and tonal data for PDE based inpainting Image registration using phase amplitude separation Rotation invariance in exemplar based image inpainting Convective regularization for optical flow A variational method for quantitative photoacoustic tomography with piecewise constant coefficients On optical flow models for variational motion estimation Bilevel approaches for learning of variational imaging models Part II Non degenerate forms of the generalized Euler Lagrange condition for state constrained optimal control problems The Purcell three link swimmer some geometric and numerical aspects related to periodic optimal controls Controllability of Keplerian motion with low thrust control systems Higher variational equation techniques for the integrability of homogeneous potentials Introduction to KAM theory with a view to celestial mechanics Invariants of contact sub pseudo Riemannian structures and Einstein Weyl geometry Time optimal control for a perturbed Brockett integrator Twist maps and Arnold diffusion for diffeomorphisms A Hamiltonian approach to sufficiency in optimal control with minimal regularity conditions Part I Index

A Toolbox for Digital Twins Mark Asch, 2022-08-04 This book brings together the mathematical and numerical frameworks needed for developing digital twins Starting from the basics probability statistics

numerical methods optimization and machine learning and moving on to data assimilation inverse problems and Bayesian uncertainty quantification the book provides a comprehensive toolbox for digital twins Emphasis is also placed on the design process denoted as the inference cycle the aim of which is to propose a global methodology for complex problems Readers will find guidelines and decision trees to help them choose the right tools for the job a comprehensive reference section with all recent methods covering both model based and data driven approaches a vast selection of examples and all accompanying code and a companion website containing updates case studies and extended material A Toolbox for Digital Twins From Model Based to Data Driven is for researchers and engineers engineering students and scientists in any domain where data and models need to be coupled to produce digital twins

Active Subspaces Paul G. Constantine, 2015-03-17 Scientists and engineers use computer simulations to study relationships between a model's input parameters and its outputs However thorough parameter studies are challenging if not impossible when the simulation is expensive and the model has several inputs To enable studies in these instances the engineer may attempt to reduce the dimension of the model's input parameter space Active subspaces are an emerging set of dimension reduction tools that identify important directions in the parameter space This book describes techniques for discovering a model's active subspace and proposes methods for exploiting the reduced dimension to enable otherwise infeasible parameter studies Readers will find new ideas for dimension reduction easy to implement algorithms and several examples of active subspaces in action

An Introduction to Statistical Computing Jochen Voss, 2013-08-28 A comprehensive introduction to sampling based methods in statistical computing The use of computers in mathematics and statistics has opened up a wide range of techniques for studying otherwise intractable problems Sampling based simulation techniques are now an invaluable tool for exploring statistical models This book gives a comprehensive introduction to the exciting area of sampling based methods An Introduction to Statistical Computing introduces the classical topics of random number generation and Monte Carlo methods It also includes some advanced methods such as the reversible jump Markov chain Monte Carlo algorithm and modern methods such as approximate Bayesian computation and multilevel Monte Carlo techniques An Introduction to Statistical Computing Fully covers the traditional topics of statistical computing Discusses both practical aspects and the theoretical background Includes a chapter about continuous time models Illustrates all methods using examples and exercises Provides answers to the exercises using the statistical computing environment R the corresponding source code is available online Includes an introduction to programming in R This book is mostly self contained the only prerequisites are basic knowledge of probability up to the law of large numbers Careful presentation and examples make this book accessible to a wide range of students and suitable for self study or as the basis of a taught course

Advanced Electromagnetic Models for Materials Characterization and Nondestructive Evaluation Harold A Sabbagh, R. Kim Murphy, Elias H. Sabbagh, Liming Zhou, Russell Wincheski, 2021-03-19 This book expands on the subject matter of Computational Electromagnetics and Model Based Inversion A Modern Paradigm

for Eddy Current Nondestructive Evaluation It includes a voxel based inversion methods which are generalizations of model based algorithms b a complete electromagnetic model of advanced composites and other novel exotic materials stressing the highly anisotropic nature of these materials as well as giving a number of applications to nondestructive evaluation and c an up to date discussion of stochastic integral equations and propagation of uncertainty models in nondestructive evaluation As such the book combines research started twenty five years ago in advanced composites and voxel based algorithms but published in scattered journal articles as well as recent research in stochastic integral equations All of these areas are of considerable interest to the aerospace nuclear power civil infrastructure materials characterization and biomedical industries The book covers the topic of computational electromagnetics in eddy current nondestructive evaluation NDE by emphasizing three distinct topics a fundamental mathematical principles of volume integral equations as a subset of computational electromagnetics b mathematical algorithms applied to signal processing and inverse scattering problems and c applications of these two topics to problems in which real and model data are used It is therefore more than an academic exercise and is valuable to users of eddy current NDE technology in industries as varied as nuclear power aerospace materials characterization and biomedical imaging

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Large Scale Inverse Problems And Quantification Of Uncertainty Introduction

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