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Geometric Numerical Integration

Structure-Preserving Algorithms for Ordinary Differential Equations

Second Edition

Springer

Geometric Numerical Integration Structure Preserving Algorithms For Ordinary Differential Equations Springer

Massih-Reza Amini,Stéphane Canu,Asja Fischer,Tias Guns,Petra Kralj Novak,Grigorios Tsoumakas

Geometric Numerical Integration Structure Preserving Algorithms For Ordinary Differential Equations Springer:

Geometric Numerical Integration Ernst Hairer,Christian Lubich,Gerhard Wanner,2002 Numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions are the subject of this book A complete self contained theory of symplectic and symmetric methods which include Runge Kutta composition splitting multistep and various specially designed integrators is presented and their construction and practical merits are discussed The long time behaviour of the numerical solutions is studied using a backward error analysis modified equations combined with KAM theory The book is illustrated by many figures it treats applications from physics and astronomy and contains many numerical experiments and comparisons of different approaches

Geometric Numerical Integration Ernst Hairer,Christian Lubich,Gerhard Wanner,2006 Provides information on numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions This book presents a theory of symplectic and symmetric methods including composition splitting multistep and various specially designed integrators **Geometric Numerical Integration** Ernst Hairer,Christian Lubich,Gerhard Wanner,2014-01-15 A Concise Introduction to Geometric Numerical Integration Sergio Blanes,Fernando Casas,2017-11-22 Discover How Geometric Integrators Preserve the Main Qualitative Properties of Continuous Dynamical Systems A Concise Introduction to Geometric Numerical Integration presents the main themes techniques and applications of geometric integrators for researchers in mathematics physics astronomy and chemistry who are already familiar with numerical tools for solving differential equations It also offers a bridge from traditional training in the numerical analysis of differential equations to understanding recent advanced research literature on numerical geometric integration The book first examines high order classical integration methods from the structure preservation point of view It then illustrates how to construct high order integrators via the composition of basic low order methods and analyzes the idea of splitting It next reviews symplectic integrators constructed directly from the theory of generating functions as well as the important category of variational integrators The authors also explain the relationship between the preservation of the geometric properties of a numerical method and the observed favorable error propagation in long time integration The book concludes with an analysis of the applicability of splitting and composition methods to certain classes of partial differential equations such as the Schr dinger equation and other evolution equations The motivation of geometric numerical integration is not only to develop numerical methods with improved qualitative behavior but also to provide more accurate long time integration results than those obtained by general purpose algorithms Accessible to researchers and post graduate students from diverse backgrounds this introductory book gets readers up to speed on the ideas methods and applications of this field Readers can reproduce the figures and results given in the text using the MATLAB programs and model files available online

Structure-Preserving Algorithms for Oscillatory Differential Equations II Xinyuan Wu,Kai Liu,Wei Shi,2016-03-03 This

book describes a variety of highly effective and efficient structure preserving algorithms for second order oscillatory differential equations Such systems arise in many branches of science and engineering and the examples in the book include systems from quantum physics celestial mechanics and electronics To accurately simulate the true behavior of such systems a numerical algorithm must preserve as much as possible their key structural properties time reversibility oscillation symplecticity and energy and momentum conservation The book describes novel advances in RKN methods ERKN methods Filon type asymptotic methods AVF methods and trigonometric Fourier collocation methods The accuracy and efficiency of each of these algorithms are tested via careful numerical simulations and their structure preserving properties are rigorously established by theoretical analysis The book also gives insights into the practical implementation of the methods This book is intended for engineers and scientists investigating oscillatory systems as well as for teachers and students who are interested in structure preserving algorithms for differential equations **Numerical Methods for Ordinary Differential Equations** J. C. Butcher,2008-04-15 In recent years the study of numerical methods for solving ordinary differential equations has seen many new developments This second edition of the author s pioneering text is fully revised and updated to acknowledge many of these developments It includes a complete treatment of linear multistep methods whilst maintaining its unique and comprehensive emphasis on Runge Kutta methods and general linear methods Although the specialist topics are taken to an advanced level the entry point to the volume as a whole is not especially demanding Early chapters provide a wide ranging introduction to differential equations and difference equations together with a survey of numerical differential equation methods based on the fundamental Euler method with more sophisticated methods presented as generalizations of Euler Features of the book include Introductory work on differential and difference equations A comprehensive introduction to the theory and practice of solving ordinary differential equations numerically A detailed analysis of Runge Kutta methods and of linear multistep methods A complete study of general linear methods from both theoretical and practical points of view The latest results on practical general linear methods and their implementation A balance between informal discussion and rigorous mathematical style Examples and exercises integrated into each chapter enhancing the suitability of the book as a course text or a self study treatise Written in a lucid style by one of the worlds leading authorities on numerical methods for ordinary differential equations and drawing upon his vast experience this new edition provides an accessible and self contained introduction ideal for researchers and students following courses on numerical methods engineering and other sciences **Handbook of Ordinary Differential Equations** Andrei D. Polyanin,Valentin F. Zaitsev,2017-11-15 The Handbook of Ordinary Differential Equations Exact Solutions Methods and Problems is an exceptional and complete reference for scientists and engineers as it contains over 7 000 ordinary differential equations with solutions This book contains more equations and methods used in the field than any other book currently available Included in the handbook are exact asymptotic approximate analytical numerical symbolic and qualitative methods that are used for solving and analyzing

linear and nonlinear equations The authors also present formulas for effective construction of solutions and many different equations arising in various applications like heat transfer elasticity hydrodynamics and more This extensive handbook is the perfect resource for engineers and scientists searching for an exhaustive reservoir of information on ordinary differential equations Structure-preserving Integrators in Nonlinear Structural Dynamics and Flexible Multibody Dynamics Peter Betsch,2016-05-10 This book focuses on structure preserving numerical methods for flexible multibody dynamics including nonlinear elastodynamics and geometrically exact models for beams and shells It also deals with the newly emerging class of variational integrators as well as Lie group integrators It discusses two alternative approaches to the discretization in space of nonlinear beams and shells Firstly geometrically exact formulations which are typically used in the finite element community and secondly the absolute nodal coordinate formulation which is popular in the multibody dynamics community Concerning the discretization in time the energy momentum method and its energy decaying variants are discussed It also addresses a number of issues that have arisen in the wake of the structure preserving discretization in space Among them are the parameterization of finite rotations the incorporation of algebraic constraints and the computer implementation of the various numerical methods The practical application of structure preserving methods is illustrated by a number of examples dealing with among others nonlinear beams and shells large deformation problems long term simulations and coupled thermo mechanical multibody systems In addition it links novel time integration methods to frequently used methods in industrial multibody system simulation *Computational Science - ICCS 2006* Vassil Alexandrov,2006-05-26 The four volume set LNCS 3991 3994 constitutes the refereed proceedings of the 6th International Conference on Computational Science ICCS 2006 held in Reading UK in May 2006 The main conference and its 32 topical workshops attracted over 1400 submissions The 98 revised full papers and 29 revised poster papers of the main track presented together with 500 accepted workshop papers were carefully reviewed and selected for inclusion in the four volumes The papers span the whole range of computational science with focus on the following major themes tackling grand challenges problems modelling and simulations of complex systems scalable algorithms and tools and environments for computational science Of particular interest were the following major recent developments in novel methods and modelling of complex systems for diverse areas of science scalable scientific algorithms advanced software tools computational grids advanced numerical methods and novel application areas where the above novel models algorithms and tools can be efficiently applied such as physical systems computational and systems biology environmental systems finance and others **Topics in Multiple Time Scale Dynamics** Maximilian Engel,Hildeberto Jard¢n-Kojakhmetov,Cinzia Soresina,2024-10-21 This volume contains the proceedings of the BIRS Workshop Topics in Multiple Time Scale Dynamics held from November 27 December 2 2022 at the Banff International Research Station Banff Alberta Canada The area of multiple scale dynamics is rapidly evolving marked by significant theoretical breakthroughs and practical applications The workshop facilitated a convergence of experts from

various sub disciplines encompassing topics like blow up techniques for ordinary differential equations ODEs singular perturbation theory for stochastic differential equations SDE homogenization and averaging slow fast maps numerical approaches and network dynamics including their applications in neuroscience and climate science This volume provides a wide ranging perspective on the current challenging subjects being explored in the field including themes such as novel approaches to blowing up and canard theory in unique contexts complex multi scale challenges in PDEs and the role of stochasticity in multiple scale systems **Machine Learning, Low-Rank Approximations and Reduced Order Modeling in Computational Mechanics** Felix Fritzen,David Ryckelynck,2019-09-18 The use of machine learning in mechanics is booming Algorithms inspired by developments in the field of artificial intelligence today cover increasingly varied fields of application This book illustrates recent results on coupling machine learning with computational mechanics particularly for the construction of surrogate models or reduced order models The articles contained in this compilation were presented at the EUROMECH Colloquium 597 Reduced Order Modeling in Mechanics of Materials held in Bad Herrenalb Germany from August 28th to August 31th 2018 In this book Artificial Neural Networks are coupled to physics based models The tensor format of simulation data is exploited in surrogate models or for data pruning Various reduced order models are proposed via machine learning strategies applied to simulation data Since reduced order models have specific approximation errors error estimators are also proposed in this book The proposed numerical examples are very close to engineering problems The reader would find this book to be a useful reference in identifying progress in machine learning and reduced order modeling for computational mechanics Variational Calculus with Engineering Applications Constantin Udriste,Ionel Tevy,2022-10-24 VARIATIONAL CALCULUS WITH ENGINEERING APPLICATIONS A comprehensive overview of foundational variational methods for problems in engineering Variational calculus is a field in which small alterations in functions and functionals are used to find their relevant maxima and minima It is a potent tool for addressing a range of dynamic problems with otherwise counter intuitive solutions particularly ones incorporating multiple confounding variables Its value in engineering fields where materials and geometric configurations can produce highly specific problems with unconventional or unintuitive solutions is considerable Variational Calculus with Engineering Applications provides a comprehensive survey of this toolkit and its engineering applications Balancing theory and practice it offers a thorough and accessible introduction to the field pioneered by Euler Lagrange and Hamilton offering tools that can be every bit as powerful as the better known Newtonian mechanics It is an indispensable resource for those looking for engineering oriented overview of a subject whose capacity to provide engineering solutions is only increasing Variational Calculus with Engineering Applications readers will also find Discussion of subjects including variational principles levitation geometric dynamics and more Examples and instructional problems in every chapter along with MAPLE codes for performing the simulations described in each Engineering applications based on simple curvilinear and multiple integral functionals

Variational Calculus with Engineering Applications is ideal for advanced students researchers and instructors in engineering and materials science *Geometric Numerical Integration and Schrödinger Equations* Erwan Faou,2012 The goal of geometric numerical integration is the simulation of evolution equations possessing geometric properties over long periods of time Of particular importance are Hamiltonian partial differential equations typically arising in application fields such as quantum mechanics or wave propagation phenomena They exhibit many important dynamical features such as energy preservation and conservation of adiabatic invariants over long periods of time In this setting a natural question is how and to which extent the reproduction of such long time qualitative behavior can be ensured by numerical schemes Starting from numerical examples these notes provide a detailed analysis of the Schrodinger equation in a simple setting periodic boundary conditions polynomial nonlinearities approximated by symplectic splitting methods Analysis of stability and instability phenomena induced by space and time discretization are given and rigorous mathematical explanations are provided for them The book grew out of a graduate level course and is of interest to researchers and students seeking an introduction to the subject matter **Machine Learning and Knowledge Discovery in Databases** Massih-Reza Amini,Stéphane Canu,Asja Fischer,Tias Guns,Petra Kralj Novak,Grigorios Tsoumakas,2023-03-16 The multi volume set LNAI 13713 until 13718 constitutes the refereed proceedings of the European Conference on Machine Learning and Knowledge Discovery in Databases ECML PKDD 2022 which took place in Grenoble France in September 2022 The 236 full papers presented in these proceedings were carefully reviewed and selected from a total of 1060 submissions In addition the proceedings include 17 Demo Track contributions The volumes are organized in topical sections as follows Part I Clustering and dimensionality reduction anomaly detection interpretability and explainability ranking and recommender systems transfer and multitask learning Part II Networks and graphs knowledge graphs social network analysis graph neural networks natural language processing and text mining conversational systems Part III Deep learning robust and adversarial machine learning generative models computer vision meta learning neural architecture search Part IV Reinforcement learning multi agent reinforcement learning bandits and online learning active and semi supervised learning private and federated learning Part V Supervised learning probabilistic inference optimal transport optimization quantum hardware sustainability Part VI Time series financial machine learning applications applications transportation demo track **The Cell Method** Elena Ferretti,2014-02-02 The Cell Method CM is a computational tool that maintains critical multidimensional attributes of physical phenomena in analysis This information is neglected in the differential formulations of the classical approaches of finite element boundary element finite volume and finite difference analysis often leading to numerical instabilities and spurious results This book highlights the central theoretical concepts of the CM that preserve a more accurate and precise representation of the geometric and topological features of variables for practical problem solving Important applications occur in fields such as electromagnetics electrodynamics solid mechanics and fluids CM addresses non locality in continuum mechanics an especially important

circumstance in modeling heterogeneous materials Professional engineers and scientists as well as graduate students are offered A general overview of physics and its mathematical descriptions Guidance on how to build direct discrete formulations Coverage of the governing equations of the CM including nonlocality Explanations of the use of Tonti diagrams and References for further reading **Formulation and Numerical Solution of Quantum Control Problems** Alfio Borzi,Gabriele Ciaramella,Martin Sprengel,2017-07-06 This book provides an introduction to representative nonrelativistic quantum control problems and their theoretical analysis and solution via modern computational techniques The quantum theory framework is based on the Schr dinger picture and the optimization theory which focuses on functional spaces is based on the Lagrange formalism The computational techniques represent recent developments that have resulted from combining modern numerical techniques for quantum evolutionary equations with sophisticated optimization schemes Both finite and infinite dimensional models are discussed including the three level Lambda system arising in quantum optics multispin systems in NMR a charged particle in a well potential Bose Einstein condensates multiparticle spin systems and multiparticle models in the time dependent density functional framework This self contained book covers the formulation analysis and numerical solution of quantum control problems and bridges scientific computing optimal control and exact controllability optimization with differential models and the sciences and engineering that require quantum control methods

Quantification of Uncertainty: Improving Efficiency and Technology Marta D'Elia,Max Gunzburger,Gianluigi Rozza,2020-07-30 This book explores four guiding themes reduced order modelling high dimensional problems efficient algorithms and applications by reviewing recent algorithmic and mathematical advances and the development of new research directions for uncertainty quantification in the context of partial differential equations with random inputs Highlighting the most promising approaches for near future improvements in the way uncertainty quantification problems in the partial differential equation setting are solved and gathering contributions by leading international experts the book s content will impact the scientific engineering financial economic environmental social and commercial sectors

Understanding the Discrete Element Method Hans-Georg Matuttis,Jian Chen,2014-06-23 Gives readers a more thorough understanding of DEM and equips researchers for independent work and an ability to judge methods related to simulation of polygonal particles Introduces DEM from the fundamental concepts theoretical mechanics and solidstate physics with 2D and 3D simulation methods for polygonal particles Provides the fundamentals of coding discrete element method DEM requiring little advance knowledge of granular matter or numerical simulation Highlights the numerical tricks and pitfalls that are usually only realized after years of experience with relevant simple experiments as applications Presents a logical approach starting withthe mechanical and physical bases followed by a description of the techniques and finally their applications Written by a key author presenting ideas on how to model the dynamics of angular particles using polygons and polyhedral Accompanying website includes MATLAB Programs providing the simulation code for two dimensional polygons

Recommended for researchers and graduate students who deal with particle models in areas such as fluid dynamics multi body engineering finite element methods the geosciences and multi scale physics Splitting Methods in Communication, Imaging, Science, and Engineering Roland Glowinski,Stanley J. Osher,Wotao Yin,2017-01-05 This book is about computational methods based on operator splitting It consists of twenty three chapters written by recognized splitting method contributors and practitioners and covers a vast spectrum of topics and application areas including computational mechanics computational physics image processing wireless communication nonlinear optics and finance Therefore the book presents very versatile aspects of splitting methods and their applications motivating the cross fertilization of ideas

Trends in Contemporary Mathematics Vincenzo Ancona,Elisabetta Strickland,2014-08-27 The topics faced in this book cover a large spectrum of current trends in mathematics such as Shimura varieties and the Lang lands program zonotopal combinatorics non linear potential theory variational methods in imaging Riemann holonomy and algebraic geometry mathematical problems arising in kinetic theory Boltzmann systems Pell s equations in polynomials deformation theory in non commutative algebras This work contains a selection of contributions written by international leading mathematicians who were speakers at the INdAM Day an initiative born in 2004 to present the most recent developments in contemporary mathematics

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