Geometric Numerical Integration

Structure–Preserving Algorithms for Ordinary Differential Equations

E. Hairer
C. Lubich
G. Wanner

Second Edition

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Geometric Numerical Integration Structurepreserving Algorithms For Ordinary Differential Equations

Peter Betsch

Geometric Numerical Integration Structurepreserving Algorithms For Ordinary Differential Equations:

Geometric Numerical Integration Ernst Hairer,Christian Lubich,Gerhard Wanner,2013-03-09 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,2006-02-22 This book covers numerical methods that preserve properties of Hamiltonian systems reversible systems differential equations on manifolds and problems with highly oscillatory solutions It presents a theory of symplectic and symmetric methods which include various specially designed integrators as well as discusses their construction and practical merits The long time behavior of the numerical solutions is studied using a backward error analysis combined with KAM theory *Defect Correction Methods* K. Böhmer,H.J. Stetter,Mathematisches Forschungsinstitut,1984 *Geometric Integrators for Differential Equations with Highly Oscillatory Solutions* Xinyuan Wu,Bin Wang,2021-09-28 The idea of structure preserving algorithms appeared in the 1980 s The new paradigm brought many innovative changes The new paradigm wanted to identify the long time behaviour of the solutions or the existence of conservation laws or some other qualitative feature of the dynamics Another area that has kept growing in importance within Geometric Numerical Integration is the study of highly oscillatory problems problems where the solutions are periodic or quasiperiodic and have to be studied in time intervals that include an extremely large number of periods As is known these equations cannot be solved efficiently using conventional methods A further study of novel geometric integrators has become increasingly important in recent years The objective of this monograph is to explore further geometric integrators for highly oscillatory problems that can be formulated as systems of ordinary and partial differential equations Facing challenging scientific computational problems this book presents some new perspectives of the subject matter based on theoretical derivations and mathematical analysis and provides high performance numerical simulations In order to show the long time numerical behaviour of the simulation all the integrators presented in this monograph have been tested and verified on highly oscillatory systems from a wide range of applications in the field of science and engineering They are more efficient than existing schemes in the literature for differential equations that have highly oscillatory solutions This book is useful to researchers teachers students and engineers who are interested in Geometric Integrators and their long time behaviour analysis for differential equations with highly oscillatory solutions *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   Numerical Methods for Ordinary Differential Equations David F. Griffiths,Desmond J. Higham,2010-11-11 Numerical Methods for Ordinary Differential Equations is a self contained introduction to a fundamental field of numerical analysis and scientific computation Written for undergraduate students with a mathematical background this book focuses on the analysis of numerical methods without losing sight of the practical nature of the subject It covers the topics traditionally treated in a first course but also highlights new and emerging themes Chapters are broken down into lecture sized pieces motivated and illustrated by numerous theoretical and computational examples Over 200 exercises are provided and these are starred according to their degree of difficulty Solutions to all exercises are available to authorized instructors The book covers key foundation topics o Taylor series methods o Runge Kutta methods o Linear multistep methods o Convergence o Stability and a range of modern themes o Adaptive stepsize selection o Long term dynamics o Modified equations o Geometric integration o Stochastic differential equations The prerequisite of a basic university level calculus class is assumed although appropriate background results are also summarized in appendices A dedicated website for the book containing extra information can be found via www springer com   *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 **Fundamentals of Ordinary Differential Equations** Mohit Chatterjee,2025-02-20 Fundamentals of Ordinary Differential Equations is a comprehensive guide designed for students researchers and professionals to master ODE theory and applications We cover essential principles advanced techniques and practical applications providing a well rounded resource for understanding differential equations and their real world impact The book offers a multifaceted approach from basic principles to advanced concepts catering to fields like physics engineering biology and economics Mathematical ideas are broken down with step by step explanations examples and illustrations making complex concepts accessible Real world examples throughout each chapter show how ODEs model and analyze systems in diverse disciplines We also explain numerical methods such as Euler s method Runge Kutta and finite differences equipping readers with computational tools for solving ODEs Advanced topics include bifurcation chaos theory Hamiltonian systems and singular perturbations providing an in depth grasp of ODE topics With chapter summaries exercises glossaries and additional resources Fundamentals of Ordinary Differential Equations is an essential reference for students professionals and practitioners across science and engineering fields General Linear Methods for Ordinary Differential Equations Zdzislaw Jackiewicz,2009-08-14 Learn to develop numerical methods for ordinary differential equations General Linear Methods for Ordinary Differential Equations fills a gap in the existing literature by presenting a comprehensive and up to date collection of recent advances and developments in the field This book provides modern coverage of the theory construction and implementation of both classical and modern general linear methods for solving ordinary differential equations as they apply to a variety of related areas including mathematics applied science and engineering The author provides the theoretical foundation for understanding basic concepts and presents a short introduction to ordinary differential equations that encompasses the related concepts of existence and uniqueness theory stability theory and stiff differential equations and systems In addition a thorough presentation of general linear methods explores relevant subtopics such as pre consistency consistency stage consistency zero stability convergence order and stage order conditions local

discretization error and linear stability theory Subsequent chapters feature coverage of Differential equations and systems Introduction to general linear methods GLMs Diagonally implicit multistage integration methods DIMSIMs Implementation of DIMSIMs Two step Runge Kutta TSRK methods Implementation of TSRK methods GLMs with inherent Runge Kutta stability IRKS Implementation of GLMs with IRKS General Linear Methods for Ordinary Differential Equations is an excellent book for courses on numerical ordinary differential equations at the upper undergraduate and graduate levels It is also a useful reference for academic and research professionals in the fields of computational and applied mathematics computational physics civil and chemical engineering chemistry and the life 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 Patterns of Dynamics Pavel Gurevich,Juliette Hell,Björn Sandstede,Arnd Scheel,2018-02-07 Theoretical advances in dynamical systems theory and their applications to pattern forming processes in the sciences and engineering are discussed in this volume that resulted from the conference Patterns in Dynamics held in honor of Bernold Fiedler in Berlin July 25 29 2016 The contributions build and develop mathematical techniques and use mathematical approaches for prediction and control of complex systems The underlying mathematical theories help extract structures from experimental observations and conversely shed light on the formation dynamics and control of spatio temporal patterns in applications Theoretical areas covered include geometric analysis spatial dynamics spectral theory traveling wave theory and topological data analysis also discussed are their applications to chemotaxis self organization at interfaces neuroscience and transport processes **Logarithmic Norms** Gustaf Söderlind,2024-11-11 This book offers the first comprehensive account of how the logarithmic norm is used for matrices nonlinear maps and linear differential operators with a focus on initial and boundary value problems Complementing the usual operator norm the logarithmic norm is a versatile tool which provides unique additional information on the magnitude of an operator It is instrumental in the stability theory of dynamical systems and in the theory of elliptic operator equations The text adopts a unified approach to address a wide range of themes in applied mathematics It explores the role of the logarithmic norm in scientific computing compares the operator bounds with those of spectral theory and illustrates the theory with classical models from science and engineering Many previously unpublished results are presented alongside

established material supporting researchers in applied mathematics and computational engineering who seek a systematic approach to stability and perturbation bounds in initial value problems boundary value problems and partial differential equations Primarily intended as a reference text the book can also serve as a graduate text for PhD students **Computer Algebra in Scientific Computing** François Boulier,Matthew England,Timur M. Sadykov,Evgenii V. Vorozhtsov,2020-10-17 This book constitutes the refereed proceedings of the 22nd International Workshop on Computer Algebra in Scientific Computing CASC 2020 held in Linz Austria in September 2020 The conference was held virtually due to the COVID 19 pandemic The 34 full papers presented together with 2 invited talks were carefully reviewed and selected from 41 submissions They deal with cutting edge research in all major disciplines of computer algebra The papers cover topics such as polynomial algebra symbolic and symbolic numerical computation applications of symbolic computation for investigating and solving ordinary differential equations applications of CAS in the investigation and solution of celestial mechanics problems and in mechanics physics and robotics Finite Difference Methods,Theory and Applications Ivan Dimov,István Faragó,Lubin Vulkov,2015-06-16 This book constitutes the thoroughly refereed post conference proceedings of the 6th International Conference on Finite Difference Methods FDM 2014 held in Lozenetz Bulgaria in June 2014 The 36 revised full papers were carefully reviewed and selected from 62 submissions These papers together with 12 invited papers cover topics such as finite difference and combined finite difference methods as well as finite element methods and their various applications in physics chemistry biology and finance **Mathematical Methods for Geophysics and Space Physics** William I. Newman,2016-05-03 Graduate students in the natural sciences including not only geophysics and space physics but also atmospheric and planetary physics ocean sciences and astronomy need a broad based mathematical toolbox to facilitate their research In addition they need to survey a wider array of mathematical methods that while outside their particular areas of expertise are important in related ones While it is unrealistic to expect them to develop an encyclopedic knowledge of all the methods that are out there they need to know how and where to obtain reliable and effective insights into these broader areas Here at last is a graduate textbook that provides these students with the mathematical skills they need to succeed in today s highly interdisciplinary research environment This authoritative and accessible book covers everything from the elements of vector and tensor analysis to ordinary differential equations special functions and chaos and fractals Other topics include integral transforms complex analysis and inverse theory partial differential equations of mathematical geophysics probability statistics and computational methods and much more Proven in the classroom Mathematical Methods for Geophysics and Space Physics features numerous exercises throughout as well as suggestions for further reading Provides an authoritative and accessible introduction to the subject Covers vector and tensor analysis ordinary differential equations integrals and approximations Fourier transforms diffusion and dispersion sound waves and perturbation theory randomness in data and a host of other topics Features numerous exercises throughout Ideal for

students and researchers alike An online illustration package is available to professors **Parallel Computing: Accelerating Computational Science and Engineering (CSE)** M. Bader,A. Bode,H.-J. Bungartz,2014-03-31 Parallel computing has been the enabling technology of high end machines for many years Now it has finally become the ubiquitous key to the efficient use of any kind of multi processor computer architecture from smart phones tablets embedded systems and cloud computing up to exascale computers _x000D_ This book presents the proceedings of ParCo2013 the latest edition of the biennial International Conference on Parallel Computing held from 10 to 13 September 2013 in Garching Germany The conference focused on several key parallel computing areas Themes included parallel programming models for multi and manycore CPUs GPUs FPGAs and heterogeneous platforms the performance engineering processes that must be adapted to efficiently use these new and innovative platforms novel numerical algorithms and approaches to large scale simulations of problems in science and engineering _x000D_ The conference programme also included twelve mini symposia including an industry session and a special PhD Symposium which comprehensively represented and intensified the discussion of current hot topics in high performance and parallel computing These special sessions covered large scale supercomputing novel challenges arising from parallel architectures multi manycore heterogeneous platforms FPGAs multi level algorithms as well as multi scale multi physics and multi dimensional problems _x000D_ It is clear that parallel computing including the processing of large data sets Big Data will remain a persistent driver of research in all fields of innovative computing which makes this book relevant to all those with an interest in this field **Efficient High-Order Discretizations for Computational Fluid Dynamics** Martin Kronbichler,Per-Olof Persson,2021-01-04 The book introduces modern high order methods for computational fluid dynamics As compared to low order finite volumes predominant in today s production codes higher order discretizations significantly reduce dispersion errors the main source of error in long time simulations of flow at higher Reynolds numbers A major goal of this book is to teach the basics of the discontinuous Galerkin DG method in terms of its finite volume and finite element ingredients It also discusses the computational efficiency of high order methods versus state of the art low order methods in the finite difference context given that accuracy requirements in engineering are often not overly strict The book mainly addresses researchers and doctoral students in engineering applied mathematics physics and high performance computing with a strong interest in the interdisciplinary aspects of computational fluid dynamics It is also well suited for practicing computational engineers who would like to gain an overview of discontinuous Galerkin methods modern algorithmic realizations and high performance implementations Acta Numerica 2010: Volume 19 Arieh Iserles,2010-05-27 A high impact prestigious annual publication containing invited surveys by subject leaders essential reading for all practitioners and researchers *Multibody Dynamics* Zdravko Terze,2014-06-26 By having its origin in analytical and continuum mechanics as well as in computer science and applied mathematics multibody dynamics provides a basis for analysis and virtual prototyping of innovative applications in many fields of contemporary engineering With the

utilization of computational models and algorithms that classically belonged to different fields of applied science multibody dynamics delivers reliable simulation platforms for diverse highly developed industrial products such as vehicle and railway systems aeronautical and space vehicles robotic manipulators smart structures biomechanical applications and nano technologies The chapters of this volume are based on the revised and extended versions of the selected scientific papers from amongst 255 original contributions that have been accepted to be presented within the program of the distinguished international ECCOMAS conference It reflects state of the art in the advances of multibody dynamics providing excellent insight in the recent scientific developments in this prominent field of computational mechanics and contemporary engineering   Hydro-Environmental Analysis James L. Martin,2013-12-04 Focusing on fundamental principles Hydro Environmental Analysis Freshwater Environments presents in depth information about freshwater environments and how they are influenced by regulation It provides a holistic approach exploring the factors that impact water quality and quantity and the regulations policy and management methods that are necessary to maintain this vital resource It offers a historical viewpoint as well as an overview and foundation of the physical chemical and biological characteristics affecting the management of freshwater environments The book concentrates on broad and general concepts providing an interdisciplinary foundation The author covers the methods of measurement and classification chemical physical and biological characteristics indicators of ecological health and management and restoration He also considers common indicators of environmental health characteristics and operations of regulatory control structures applicable laws and regulations and restoration methods The text delves into rivers and streams in the first half and lakes and reservoirs in the second half Each section centers on the characteristics of those systems and methods of classification and then moves on to discuss the physical chemical and biological characteristics of each In the section on lakes and reservoirs it examines the characteristics and operations of regulatory structures and presents the methods commonly used to assess the environmental health or integrity of these water bodies It also introduces considerations for restoration and presents two unique aquatic environments wetlands and reservoir tailwaters Written from an engineering perspective the book is an ideal introduction to the aquatic and limnological sciences for students of environmental science as well as students of environmental engineering It also serves as a reference for engineers and scientists involved in the management regulation or restoration of freshwater environments

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