Numerical Methods for Conservation Laws

Randall J. LeVeque

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Numerical Methods for Conservation Laws Randall J. LeVeque,2012-12-06 These notes developed from a course on the numerical solution of conservation laws first taught at the University of Washington in the fall of 1988 and then at ETH during the following spring The overall emphasis is on studying the mathematical tools that are essential in de veloping analyzing and successfully using numerical methods for nonlinear systems of conservation laws particularly for problems involving shock waves A reasonable un derstanding of the mathematical structure of these equations and their solutions is first required and Part I of these notes deals with this theory Part II deals more directly with numerical methods again with the emphasis on general tools that are of broad use I have stressed the underlying ideas used in various classes of methods rather than present ing the most sophisticated methods in great detail My aim was to provide a sufficient background that students could then approach the current research literature with the necessary tools and understanding Without the wonders of TeX and LaTeX these notes would never have been put together The professional looking results perhaps obscure the fact that these are indeed lecture notes Some sections have been reworked several times by now but others are still preliminary I can only hope that the errors are not too blatant Moreover the breadth and depth of coverage was limited by the length of these courses and some parts are rather sketchy **Numerical Methods for Conservation Laws** Jan S. Hesthaven,2018-01-30 Conservation laws are the mathematical expression of the principles of conservation and provide effective and accurate predictive models of our physical world Although intense research activity during the last decades has led to substantial advances in the development of powerful computational methods for conservation laws their solution remains a challenge and many questions are left open thus it is an active and fruitful area of research Numerical Methods for Conservation Laws From Analysis to Algorithms offers the first comprehensive introduction to modern computational methods and their analysis for hyperbolic conservation laws building on intense research activities for more than four decades of development discusses classic results on monotone and finite difference finite volume schemes but emphasizes the successful development of high order accurate methods for hyperbolic conservation laws addresses modern concepts of TVD and entropy stability strongly stable Runge Kutta schemes and limiter based methods before discussing essentially nonoscillatory schemes discontinuous Galerkin methods and spectral methods explores algorithmic aspects of these methods emphasizing one and two dimensional problems and the development and analysis of an extensive range of methods includes MATLAB software with which all main methods and computational results in the book can be reproduced and demonstrates the performance of many methods on a set of benchmark problems to allow direct comparisons Code and other supplemental material are available online at www siam org books cs18   Numerical Methods for Conservation Laws Randall J. LeVeque,1990 These notes developed from a course on the numerical solution of conservation laws first taught at the University of Washington in the fall of 1988 and then at ETH during the following spring The overall emphasis is on studying

the mathematical tools that are essential in de veloping analyzing and successfully using numerical methods for nonlinear systems of conservation laws particularly for problems involving shock waves A reasonable un derstanding of the mathematical structure of these equations and their solutions is first required and Part I of these notes deals with this theory Part II deals more directly with numerical methods again with the emphasis on general tools that are of broad use I have stressed the underlying ideas used in various classes of methods rather than present ing the most sophisticated methods in great detail My aim was to provide a sufficient background that students could then approach the current research literature with the necessary tools and understanding vVithout the wonders of TeX and LaTeX these notes would never have been put together The professional looking results perhaps obscure the fact that these are indeed lecture notes Some sections have been reworked several times by now but others are still preliminary I can only hope that the errors are not too blatant Moreover the breadth and depth of coverage was limited by the length of these courses and some parts are rather sketchy *Numerical Methods for Conservation Laws* Leveque,2014-01-15 **Numerical Methods for Conservation Laws** Randall J. LeVeque,1990-01-01 **Parallel Numerical Methods in Conservation Laws** Jayesh Badwaik,2024 *Asymptotic-induced Numerical Methods for Conservation Laws* Institute for Computer Applications in Science and Engineering,M. Garbey,Jeffrey Scott Scroggs,1990 **Numerical Methods for Conservation Laws of Mixed Type** Huiing Gau,1995 **Asymptotic-Induced Numerical Methods for Conservation Laws** National Aeronautics and Space Adm Nasa,2018-10-24 Asymptotic induced methods are presented for the numerical solution of hyperbolic conservation laws with or without viscosity The methods consist of multiple stages The first stage is to obtain a first approximation by using a first order method such as the Godunov scheme Subsequent stages of the method involve solving internal layer problems identified by using techniques derived via asymptotics Finally a residual correction increases the accuracy of the scheme The method is derived and justified with singular perturbation techniques Garbey Marc and Scroggs Jeffrey S Unspecified Center NAS1 18605 W 31 109 ENG 38 **Numerical Schemes for Conservation Laws** Dietmar Kröner,1997-03-06 This book systematically studies upwind methods for initial value problems for scalar conservation laws in one and multidimensions The mathematical theory of convergence theory and of a priori error estimates is presented in detail for structure finite difference methods as well as for unstructured grids finite volume methods Higher order schemes are also included In the second part of the book the algorithms for scalar equations are generalized into systems of conversation laws in one and multidimensions The most powerful schemes for the discretization of systems are described and numerical examples are presented In particular local grid refinement has been taken into account The initial boundary value problem is also considered for linear systems and nonlinear scalar conservation laws <u>Numerical Methods for Eulerian and Lagrangian Conservation Laws</u> Bruno Després,2017-07-09 This book focuses on the interplay between Eulerian and Lagrangian conservation laws for systems that admit physical motivation and originate from continuum mechanics Ultimately it

highlights what is specific to and beneficial in the Lagrangian approach and its numerical methods The two first chapters present a selection of well known features of conservation laws and prepare readers for the subsequent chapters which are dedicated to the analysis and discretization of Lagrangian systems The text is at the frontier of applied mathematics and scientific computing and appeals to students and researchers interested in Lagrangian based computational fluid dynamics It also serves as an introduction to the recent corner based Lagrangian finite volume techniques **Property-preserving Numerical Schemes For Conservation Laws** Dmitri Kuzmin,Hennes Hajduk,2023-08-28 High order numerical methods for hyperbolic conservation laws do not guarantee the validity of constraints that physically meaningful approximations are supposed to satisfy The finite volume and finite element schemes summarized in this book use limiting techniques to enforce discrete maximum principles and entropy inequalities Spurious oscillations are prevented using artificial viscosity operators and or essentially nonoscillatory reconstructions An introduction to classical nonlinear stabilization approaches is given in the simple context of one dimensional finite volume discretizations Subsequent chapters of Part I are focused on recent extensions to continuous and discontinuous Galerkin methods Many of the algorithms presented in these chapters were developed by the authors and their collaborators Part II gives a deeper insight into the mathematical theory of property preserving numerical schemes It begins with a review of the convergence theory for finite volume methods and ends with analysis of algebraic flux correction schemes for finite elements In addition to providing ready to use algorithms this text explains the design principles behind such algorithms and shows how to put theory into practice Although the book is based on lecture notes written for an advanced graduate level course it is also aimed at senior researchers who develop and analyze numerical methods for hyperbolic problems *Some Results on Numerical Methods for Hyperbolic Conservation Laws* Huanan Yang,1989   A Study of Numerical Methods for Hyperbolic Conservation Laws with Stiff Source Terms Randall J. LeVeque,1988   Numerical Methods for One-dimensional Hyperbolic Conservation Laws Adriaan Cornelis Berkenbosch,Enrique Francisco Kaasschieter,Johannes Hendrikus Maria Thije Boonkkamp,1992   *An Introduction to Recent Developments in Theory and Numerics for Conservation Laws* Dietmar Kröner,Mario Ohlberger,Christian Rohde,2012-12-06 The book concerns theoretical and numerical aspects of systems of conservation laws which can be considered as a mathematical model for the flows of inviscid compressible fluids Five leading specialists in this area give an overview of the recent results which include kinetic methods non classical shock waves viscosity and relaxation methods a posteriori error estimates numerical schemes of higher order on unstructured grids in 3 D preconditioning and symmetrization of the Euler and Navier Stokes equations This book will prove to be very useful for scientists working in mathematics computational fluid mechanics aerodynamics and astrophysics as well as for graduate students who want to learn about new developments in this area **Uncertainty Quantification and Numerical Methods for Conservation Laws** Mass Per Pettersson,2013 Conservation laws with uncertain initial and boundary conditions are approximated using a

generalized polynomial chaos expansion approach where the solution is represented as a generalized Fourier series of stochastic basis functions e g orthogonal polynomials or wavelets The stochastic Galerkin method is used to project the governing partial differential equation onto the stochastic basis functions to obtain an extended deterministic system The stochastic Galerkin and collocation methods are used to solve an advection diffusion equation with uncertain viscosity We investigate well posedness monotonicity and stability for the stochastic Galerkin system High order summation by parts operators and weak imposition of boundary conditions are used to prove stability We investigate the impact of the total spatial operator on the convergence to steady state Next we apply the stochastic Galerkin method to Burgers equation with uncertain boundary conditions An analysis of the truncated polynomial chaos system presents a qualitative description of the development of the solution over time An analytical solution is derived and the true polynomial chaos coefficients are shown to be smooth while the corresponding coefficients of the truncated stochastic Galerkin formulation are shown to be discontinuous We discuss the problematic implications of the lack of known boundary data and possible ways of imposing stable and accurate boundary conditions We present a new fully intrusive method for the Euler equations subject to uncertainty based on a Roe variable transformation The Roe formulation saves computational cost compared to the formulation based on expansion of conservative variables Moreover it is more robust and can handle cases of supersonic flow for which the conservative variable formulation fails to produce a bounded solution A multiwavelet basis that can handle discontinuities in a robust way is used Finally we investigate a two phase flow problem Based on regularity analysis of the generalized polynomial chaos coefficients we present a hybrid method where solution regions of varying smoothness are coupled weakly through interfaces In this way we couple smooth solutions solved with high order finite difference methods with non smooth solutions solved for with shock capturing methods **A Study of Numerical Methods for Hyperbolic Conservation Laws with Stiff Source Terms** National Aeronautics and Space Administration (NASA),2018-06-28 The proper modeling of nonequilibrium gas dynamics is required in certain regimes of hypersonic flow For inviscid flow this gives a system of conservation laws coupled with source terms representing the chemistry Often a wide range of time scales is present in the problem leading to numerical difficulties as in stiff systems of ordinary differential equations Stability can be achieved by using implicit methods but other numerical difficulties are observed The behavior of typical numerical methods on a simple advection equation with a parameter dependent source term was studied Two approaches to incorporate the source term were utilized MacCormack type predictor corrector methods with flux limiters and splitting methods in which the fluid dynamics and chemistry are handled in separate steps Various comparisons over a wide range of parameter values were made In the stiff case where the solution contains discontinuities incorrect numerical propagation speeds are observed with all of the methods considered This phenomenon is studied and explained Leveque R J and Yee H C Ames Research Center <u>Compact Higher-order Numerical Methods for Hyperbolic Conservation Laws</u> Robert Byron Lowrie,1996

Godunov Methods E.F. Toro,2012-12-06 This edited review book on Godunov methods contains 97 articles all of which were presented at the international conference on Godunov Methods Theory and Applications held at Oxford in October 1999 to commemo rate the 70th birthday of the Russian mathematician Sergei K Godunov The meeting enjoyed the participation of 140 scientists from 20 countries one of the participants commented everyone is here meaning that virtu ally everybody who had made a significant contribution to the general area of numerical methods for hyperbolic conservation laws along the lines first proposed by Godunov in the fifties was present at the meeting Sadly there were important absentees who due to personal circumstance could not at tend this very exciting gathering The central theme o the meeting and of this book was numerical methods for hyperbolic conservation laws fol lowing Godunov s key ideas contained in his celebrated paper of 1959 But Godunov s contributions to science are not restricted to Godunov s method

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