

Numerical Solution of PDEs

3.1 SOME PDE BASICS

Our physical world is most generally described in scientific and engineering terms with respect to three-dimensional space and time, which is commonly referred to as *space-time*. An *evolution* equation is a *partial differential equation* (PDE) that describes mathematically the evolution over space and time of a physical system or process. PDEs are therefore among the most widely used forms of mathematics in many disciplines. As a consequence, methods for the solution of PDEs, such as the method of lines (MOL) [Sch-91], are of broad interest in science and engineering. Our main focus will be on MOL.

As a basic illustrative example of a PDE, we consider

$$\frac{\partial u}{\partial t} = D \frac{\partial^2 u}{\partial x^2}, \quad (3.1)$$

where

- u is a dependent variable (dependent on x and t)
- t is an independent variable representing time
- x is an independent variable representing one dimension of three-dimensional space
- D real positive constant, explained later.

Note that eqn. (3.1) has two independent variables, x and t , which is the reason it is classified as a PDE (any differential equation with *more than one independent variable is a PDE*). A differential equation with only one independent variable is generally termed an *ordinary differential equation* (ODE); we will consider ODEs later as part of the MOL.

Equation (3.1) is termed the *diffusion equation* or *heat equation*. When applied to heat transfer, it is *Fourier's second law*; the dependent variable u is temperature and D is the *thermal diffusivity*. When eqn. (3.1) is applied to mass diffusion, it is *Fick's second law*; u is mass concentration and D is the *coefficient of diffusion* or the *diffusivity*.

The symbol $\frac{\partial u}{\partial t}$ is a partial derivative of u with respect to t (x is held constant when taking the derivative, which is why *partial* is used to describe this derivative). Equation (3.1) is *first order in t* because the highest order partial derivative in t is first order; it is *second order in x* because the highest order derivative in x is second order. Equation (3.1)

Adaptive Numerical Solution Of Pdes Adaptive Numerical Solution Of Pdes

Michael Rajnik



Adaptive Numerical Solution Of Pdes Adaptive Numerical Solution Of Pdes:

Adaptive Numerical Solution of PDEs Peter Deuflhard, Martin Weiser, 2012-08-31 This book deals with the general topic Numerical solution of partial differential equations PDEs with a focus on adaptivity of discretizations in space and time By and large introductory textbooks like Numerical Analysis in Modern Scientific Computing by Deuflhard and Hohmann should suffice as a prerequisite The emphasis lies on elliptic and parabolic systems Hyperbolic conservation laws are treated only on an elementary level excluding turbulence Numerical Analysis is clearly understood as part of Scientific Computing The focus is on the efficiency of algorithms i e speed reliability and robustness which directly leads to the concept of adaptivity in algorithms The theoretical derivation and analysis is kept as elementary as possible Nevertheless required somewhat more sophisticated mathematical theory is summarized in comprehensive form in an appendix Complex relations are explained by numerous figures and illustrating examples Non trivial problems from regenerative energy nanotechnology surgery and physiology are inserted The text will appeal to graduate students and researchers on the job in mathematics science and technology Conceptually it has been written as a textbook including exercises and a software list but at the same time it should be well suited for self study

Modeling, Mesh Generation, and Adaptive Numerical Methods for Partial Differential Equations Ivo Babuska, Joseph E Flaherty, William D Henshaw, 1995-07-14

Numerical Solution of PDEs Using Adaptive Finite Difference Methods Yiqi Qiu, 1997

Adaptive Multilevel Solution of Nonlinear Parabolic PDE Systems Jens Lang, 2013-06-29 Nowadays there is an increasing emphasis on all aspects of adaptively generating a grid that evolves with the solution of a PDE Another challenge is to develop efficient higher order one step integration methods which can handle very stiff equations and which allow us to accommodate a spatial grid in each time step without any specific difficulties In this monograph a combination of both error controlled grid refinement and one step methods of Rosenbrock type is presented It is my intention to impart the beauty and complexity found in the theoretical investigation of the adaptive algorithm proposed here in its realization and in solving non trivial complex problems I hope that this method will find many more interesting applications Berlin Dahlem May 2000 Jens Lang Acknowledgements I have looked forward to writing this section since it is a pleasure for me to thank all friends who made this work possible and provided valuable input I would like to express my gratitude to Peter Deuflhard for giving me the opportunity to work in the field of Scientific Computing I have benefited immensely from his help to get the right perspectives and from his continuous encouragement and support over several years He certainly will forgive me the use of Rosenbrock methods rather than extrapolation methods to integrate in time

Adaptive Method of Lines A. Vande Wouwer, Ph. Saucez, W.E. Schiesser, 2001-04-18 The general Method of Lines MOL procedure provides a flexible format for the solution of all the major classes of partial differential equations PDEs and is particularly well suited to evolutionary nonlinear wave PDEs Despite its utility however there are relatively few texts that explore it at a more advanced level and reflect the methods

Adaptive Computational

Methods for Partial Differential Equations Ivo Babushka, Jagdish Chandra, Joseph E. Flaherty, 1983-01-01 List of participants Elliptic equations Parabolic equations Hyperbolic equations **Parallel Solution of Partial Differential Equations** Petter Bjørstad, Mitchell Luskin, 2012-12-06 This IMA Volume in Mathematics and its Applications PARALLEL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS is based on the proceedings of a workshop with the same title The work shop was an integral part of the 1996 97 IMA program on MATHEMATICS IN HIGH PERFORMANCE COMPUTING I would like to thank Petter Bjørstad of the Institutt for Informatikk University of Bergen and Mitchell Luskin of the School of Mathematics University of Minnesota for their excellent work as organizers of the meeting and for editing the proceedings I also take this opportunity to thank the National Science Foundation NSF Department of Energy DOE and the Army Research Office ARO whose financial support made the workshop possible Willard Miller Jr Professor and Director v PREFACE The numerical solution of partial differential equations has been of major importance to the development of many technologies and has been the target of much of the development of parallel computer hardware and software Parallel computers offer the promise of greatly increased performance and the routine calculation of previously intractable problems The papers in this volume were presented at the IMA workshop on the Parallel Solution of PDE held during June 9-13 1997 The workshop brought together leading numerical analysts computer scientists and engineers to assess the state of the art and to consider future directions

Fourth International Symposium on Domain Decomposition Methods for Partial Differential Equations R. Glowinski, 1991-01-01 Focuses on the notion that by breaking the domain of the original problem into subdomains such an approach can if properly implemented lead to a considerable speedup The methods are particularly well suited for parallel computers *Partial Differential Equations* D. Sloan, S. Vandewalle, E. Süli, 2012-12-02 homepage [sac.cam.ac.uk/na2000/index.html](#) 7 Volume Set now available at special set price Over the second half of the 20th century the subject area loosely referred to as numerical analysis of partial differential equations PDEs has undergone unprecedented development At its practical end the vigorous growth and steady diversification of the field were stimulated by the demand for accurate and reliable tools for computational modelling in physical sciences and engineering and by the rapid development of computer hardware and architecture At the more theoretical end the analytical insight into the underlying stability and accuracy properties of computational algorithms for PDEs was deepened by building upon recent progress in mathematical analysis and in the theory of PDEs To embark on a comprehensive review of the field of numerical analysis of partial differential equations within a single volume of this journal would have been an impossible task Indeed the 16 contributions included here by some of the foremost world authorities in the subject represent only a small sample of the major developments We hope that these articles will nevertheless provide the reader with a stimulating glimpse into this diverse exciting and important field The opening paper by Thomas reviews the history of numerical analysis of PDEs starting with the 1928 paper by Courant Friedrichs and Lewy on the solution of problems of mathematical physics by means of finite differences This excellent survey

takes the reader through the development of finite differences for elliptic problems from the 1930s and the intense study of finite differences for general initial value problems during the 1950s and 1960s The formulation of the concept of stability is explored in the Lax equivalence theorem and the Kreiss matrix lemmas Reference is made to the introduction of the finite element method by structural engineers and a description is given of the subsequent development and mathematical analysis of the finite element method with piecewise polynomial approximating functions The penultimate section of Thom e s survey deals with other classes of approximation methods and this covers methods such as collocation methods spectral methods finite volume methods and boundary integral methods The final section is devoted to numerical linear algebra for elliptic problems The next three papers by Bialecki and Fairweather Hesthaven and Gottlieb and Dahmen describe respectively spline collocation methods spectral methods and wavelet methods The work by Bialecki and Fairweather is a comprehensive overview of orthogonal spline collocation from its first appearance to the latest mathematical developments and applications The emphasis throughout is on problems in two space dimensions The paper by Hesthaven and Gottlieb presents a review of Fourier and Chebyshev pseudospectral methods for the solution of hyperbolic PDEs Particular emphasis is placed on the treatment of boundaries stability of time discretisations treatment of non smooth solutions and multidomain techniques The paper gives a clear view of the advances that have been made over the last decade in solving hyperbolic problems by means of spectral methods but it shows that many critical issues remain open The paper by Dahmen reviews the recent rapid growth in the use of wavelet methods for PDEs The author focuses on the use of adaptivity where significant successes have recently been achieved He describes the potential weaknesses of wavelet methods as well as the perceived strengths thus giving a balanced view that should encourage the study of wavelet methods

Geometric Partial Differential Equations - Part I, 2020-01-14 Besides their intrinsic mathematical interest geometric partial differential equations PDEs are ubiquitous in many scientific engineering and industrial applications They represent an intellectual challenge and have received a great deal of attention recently The purpose of this volume is to provide a missing reference consisting of self contained and comprehensive presentations It includes basic ideas analysis and applications of state of the art fundamental algorithms for the approximation of geometric PDEs together with their impacts in a variety of fields within mathematics science and engineering About every aspect of computational geometric PDEs is discussed in this and a companion volume Topics in this volume include stationary and time dependent surface PDEs for geometric flows large deformations of nonlinearly geometric plates and rods level set and phase field methods and applications free boundary problems discrete Riemannian calculus and morphing fully nonlinear PDEs including Monge Ampere equations and PDE constrained optimization Each chapter is a complete essay at the research level but accessible to junior researchers and students The intent is to provide a comprehensive description of algorithms and their analysis for a specific geometric PDE class starting from basic concepts and concluding with interesting applications Each chapter is thus useful as an introduction to a research area as well as a

teaching resource and provides numerous pointers to the literature for further reading The authors of each chapter are world leaders in their field of expertise and skillful writers This book is thus meant to provide an invaluable readable and enjoyable account of computational geometric PDEs

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