Jie Shen Tao Tang Li-Lian Wang

# Spectral Methods

Algorithms, Analysis and Applications



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Spectral Methods Jie Shen, Tao Tang, Li-Lian Wang, 2011-08-25 Along with finite differences and finite elements spectral methods are one of the three main methodologies for solving partial differential equations on computers This book provides a detailed presentation of basic spectral algorithms as well as a systematical presentation of basic convergence theory and error analysis for spectral methods Readers of this book will be exposed to a unified framework for designing and analyzing spectral algorithms for a variety of problems including in particular high order differential equations and problems in unbounded domains. The book contains a large number of figures which are designed to illustrate various concepts stressed in the book A set of basic matlab codes has been made available online to help the readers to develop their own spectral codes for their specific applications **Scientific Computing** Bertil Gustafsson, 2018-10-03 This book explores the most significant computational methods and the history of their development It begins with the earliest mathematical numerical achievements made by the Babylonians and the Greeks followed by the period beginning in the 16th century For several centuries the main scientific challenge concerned the mechanics of planetary dynamics and the book describes the basic numerical methods of that time In turn at the end of the Second World War scientific computing took a giant step forward with the advent of electronic computers which greatly accelerated the development of numerical methods As a result scientific computing became established as a third scientific method in addition to the two traditional branches theory and experimentation The book traces numerical methods journey back to their origins and to the people who invented them while also briefly examining the development of electronic computers over the years Featuring 163 references and more than 100 figures many of them portraits or photos of key historical figures the book provides a unique historical perspective on the general field of scientific computing making it a valuable resource for all students and professionals interested in the history of numerical analysis and computing and for a broader readership alike **Navier-stokes Equations In Planar Domains** Matania Ben-artzi, Jean Pierre Croisille, Dalia Fishelov, 2013-03-07 This volume deals with the classical Navier Stokes system of equations governing the planar flow of incompressible viscid fluid It is a first of its kind book devoted to all aspects of the study of such flows ranging from theoretical to numerical including detailed accounts of classical test problems such as driven cavity and double driven cavity A comprehensive treatment of the mathematical theory developed in the last 15 years is elaborated heretofore never presented in other books It gives a detailed account of the modern compact schemes based on a pure streamfunction approach In particular a complete proof of convergence is given for the full nonlinear problem This volume aims to present a variety of numerical test problems It is therefore well positioned as a reference for both theoretical and applied mathematicians as well as a text that can be used by graduate students pursuing studies in pure or applied mathematics fluid dynamics and mathematical physics a **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

Generalized Differential and Integral Quadrature Francesco Tornabene, 2023-10-17 The main aim of this book is to analyze the mathematical fundamentals and the main features of the Generalized Differential Quadrature GDQ and Generalized Integral Quadrature GIQ techniques Furthermore another interesting aim of the present book is to shown that from the two numerical techniques mentioned above it is possible to derive two different approaches such as the Strong and Weak Finite Element Methods SFEM and WFEM that will be used to solve various structural problems and arbitrarily shaped structures A general approach to the Differential Quadrature is proposed The weighting coefficients for different basis functions and grid distributions are determined Furthermore the expressions of the principal approximating polynomials and grid distributions available in the literature are shown Besides the classic orthogonal polynomials a new class of basis functions which depend on the radial distance between the discretization points is presented. They are known as Radial Basis Functions or RBFs The general expressions for the derivative evaluation can be utilized in the local form to reduce the computational cost From this concept the Local Generalized Differential Quadrature LGDQ method is derived The Generalized Integral Quadrature GIQ technique can be used employing several basis functions without any restriction on the point distributions for the given definition domain To better underline these concepts some classical numerical integration schemes are reported such as the trapezoidal rule or the Simpson method An alternative approach based on Taylor series is also illustrated to approximate integrals This technique is named as Generalized Taylor based Integral Quadrature GTIQ method The major structural theories for the analysis of the mechanical behavior of various structures are presented in depth in the book In particular the strong and weak formulations of the corresponding governing equations are discussed and illustrated Generally speaking two formulations of the same system of governing equations can be developed which are respectively the strong and weak or variational formulations Once the governing equations that rule a generic structural problem are obtained together with the corresponding boundary conditions a differential system is written In particular the Strong Formulation SF of the governing equations is obtained The differentiability requirement instead is reduced through a weighted integral statement if the corresponding Weak Formulation WF of the governing equations is developed Thus an equivalent integral formulation is derived starting directly from the previous one In particular the formulation in hand is obtained by introducing a Lagrangian approximation of the degrees of freedom of the problem The need of studying

arbitrarily shaped domains or characterized by mechanical and geometrical discontinuities leads to the development of new numerical approaches that divide the structure in finite elements Then the strong form or the weak form of the fundamental equations are solved inside each element. The fundamental aspects of this technique which the author defined respectively Strong Formulation Finite Element Method SFEM and Weak Formulation Finite Element Method WFEM are presented in the Maximum Principle and Dynamic Programming Viscosity Solution Approach Bing Sun, Bao-Zhu Guo, Zhen-Zhen Tao, 2025-08-02 This book is concerned with optimal control problems of dynamical systems described by partial differential equations PDEs The content covers the theory and numerical algorithms starting with open loop control and ending with closed loop control It includes Pontryagin's maximum principle and the Bellman dynamic programming principle based on the notion of viscosity solution The Bellman dynamic programming method can produce the optimal control in feedback form making it more appealing for online implementations and robustness The determination of the optimal feedback control law is of fundamental importance in optimal control and can be argued as the Holy Grail of control theory. The book is organized into five chapters Chapter 1 presents necessary mathematical knowledge Chapters 2 and 3 Part 1 focus on the open loop control while Chapter 4 and 5 Part 2 focus on the closed loop control In this monograph we incorporate the notion of viscosity solution of PDE with dynamic programming approach The dynamic programming viscosity solution DPVS approach is then used to investigate optimal control problems In each problem the optimal feedback law is synthesized and numerically demonstrated The last chapter presents multiple algorithms for the DPVS approach including an upwind finite difference scheme with the convergence proof It is worth noting that the dynamic systems considered are primarily of technical or biologic origin which is a highlight of the book This book is systematic and self contained It can serve the expert as a ready reference for control theory of infinite dimensional systems These chapters taken together would also make a one semester course for graduate with first courses in PDE constrained optimal control Hygro-Thermo-Magneto-Electro-Elastic **Theory of Anisotropic Doubly-Curved Shells** Francesco Tornabene, 2023-10-13 This book aims to present in depth several Higher order Shear Deformation Theories HSDTs by means of a unified approach for studying the Hygro Thermo Magneto Electro Elastic Theory of Anisotropic Doubly Curved Shells In particular a general coupled multifield theory regarding anisotropic shell structures is provided The three dimensional multifield problem is reduced in a two dimensional one following the principles of the Equivalent Single Layer ESL approach and the Equivalent Layer Wise ELW approach setting a proper configuration model According to the adopted configuration assumptions several Higher order Shear Deformation Theories HSDTs are obtained Furthermore the strong and weak formulations of the corresponding governing equations are discussed and illustrated The approach presented in this volume is completely general and represents a valid tool to investigate the physical behavior of many arbitrarily shaped structures An isogeometric mapping procedure is also illustrated to this aim Special attention is given also to advanced and innovative constituents such as Carbon Nanotubes CNTs Variable

Angle Tow VAT composites and Functionally Graded Materials FGMs In addition several numerical applications are used to support the theoretical models Accurate efficient and reliable numerical techniques able to approximate both derivatives and integrals are considered which are respectively the Differential Quadrature DQ and Integral Quadrature IQ methods The Theory of Composite Thin Shells is derived in a simple and intuitive manner from the theory of thick and moderately thick shells First order Shear Deformation Theory or Reissner Mindlin Theory In particular the Kirchhoff Love Theory and the Membrane Theory for composite shells are shown Furthermore the Theory of Composite Arches and Beams is also exposed In particular the equations of the Timoshenko Theory and the Euler Bernoulli Theory are directly deducted from the equations of singly curved shells of translation and of plates Anisotropic Doubly-Curved Shells Francesco Tornabene, Michele Bacciocchi, 2019-11-01 This book aims to present in depth several Higher order Shear Deformation Theories HSDTs by means of a unified approach for the mechanical analysis of doubly curved shell structures made of anisotropic and composite materials In particular the strong and weak formulations of the corresponding governing equations are discussed and illustrated The approach presented in this volume is completely general and represents a valid tool to investigate the structural behavior of many arbitrarily shaped structures An isogeometric mapping procedure is also illustrated to this aim Special attention is given also to advanced and innovative constituents such as Carbon Nanotubes CNTs Variable Angle Tow VAT composites and Functionally Graded Materials FGMs In addition several numerical applications are developed to support the theoretical models Accurate efficient and reliable numerical techniques able to approximate both derivatives and integrals are presented which are respectively the Differential Quadrature DQ and Integral Quadrature IQ methods Finally two numerical techniques named Strong Formulation Finite Element Method SFEM and Weak Formulation Finite Element Method WFEM are developed to deal with multi element domains characterized by arbitrary shapes and discontinuities

Foundations of Computational Mathematics, Budapest 2011 Society for the Foundation of Computational Mathematics, 2013 A diverse collection of articles by leading experts in computational mathematics written to appeal to established researchers and non experts 
Numerical Partial Differential Equations James H. Adler, Hans De Sterck, Scott MacLachlan, Luke Olsen, 2025-03-26 This comprehensive textbook focuses on numerical methods for approximating solutions to partial differential equations PDEs The authors present a broad survey of these methods introducing readers to the central concepts of various families of discretizations and solution algorithms and laying the foundation needed to understand more advanced material The authors include over 100 well established definitions theorems corollaries and lemmas and summaries of and references to in depth treatments of more advanced mathematics when needed Numerical Partial Differential Equations is divided into four parts Part I covers basic background on PDEs and numerical methods Part II introduces the three main classes of numerical methods for PDEs that are the book s focus finite difference finite element and finite volume methods at a

more advanced level Part IV presents further high level topics on discretizations and solvers This book is intended for advanced undergraduate first year graduate and advanced graduate students in applied math as well as students in science and engineering disciplines The book will also appeal to researchers in the field of scientific computing Chapters are designed to be stand alone allowing distinct paths through the text making it appropriate for both single semester and multi semester courses It is appropriate for courses covering topics ranging from numerical methods for PDEs to numerical linear algebra

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