A Chebyshev Collocation Spectral Method For Numerical

Chebyshev polynomials crop up in virtually every area of numerical analysis, and they hold particular importance in recent advances in subjects such as orthogonal polynomials, polynomial approximation, numerical integration, and spectral methods. Yet no book dedicated to Chebyshev polynomials has been published since 1990, and even that work focused primarily on the theoretical aspects. A broad, up
overdue. Providing highly readable exposition on the subject's state of the art, Chebyshev Polynomials is just such a treatment. It includes rigorous yet down-to-earth coverage of the theory along with an in-depth look at the properties of all four kinds of Chebyshev polynomials-properties that lead to a range of results in areas such as approximation, series expansions, interpolation, quadrature, and integral
chapter, ranging in difficulty from elementary to quite advanced, reinforce the concepts and methods presented. Far from being an esoteric subject, Chebyshev polynomials lead one on a journey through all areas of numerical analysis. This book is the ideal vehicle with which to begin this journey and one that will also serve as a standard reference for many years to come.
A unified discussion of the formulation and analysis of special methods of mixed initial boundary-value problems. The focus is on the development of a new mathematical theory that explains why and how well spectral methods work. Included are interesting extensions of the classical numerical analysis.
Completely revised text applies spectral methods to boundary value, eigenvalue, and time-dependent problems, but also covers cardinal functions, matrix-solving methods, coordinate transformations, much more. Includes 7 appendices and over 160 text figures.
Second Revised Edition
Collocation Methods for Volterra Integral and Related Functional Differential Equations
Numerical Simulation
Spectral Methods for the Euler Equations
Numerical Methods for Energy Applications
This book explains how, when and why the pseudospectral approach works.
Following up the seminal Spectral Methods in Fluid Dynamics, Spectral Methods: Evolution to Complex Geometries and Applications to Fluid Dynamics contains an extensive survey of the essential algorithmic and theoretical aspects of spectral methods for complex geometries. These types of spectral methods were only just emerging at the time the earlier book was published. The discussion of spectral algorithms for linear and nonlinear fluid dynamics stability analyses is greatly expanded. The chapter on spectral algorithms for incompressible flow focuses on algorithms that have proven most useful in practice, has much greater coverage of algorithms for two or more non-periodic directions, and shows how to treat outflow boundaries. Material on spectral methods for compressible flow emphasizes boundary conditions for hyperbolic systems, algorithms for simulation of homogeneous turbulence, and improved methods for shock fitting. This book is a companion to Spectral Methods: Fundamentals in Single Domains.
This monograph presents fundamental aspects of modern spectral and other computational methods, which are not generally taught in traditional courses. It emphasizes concepts as errors, convergence, stability, order and efficiency applied to the solution of physical problems. The spectral methods consist in expanding the function to be calculated into a set of appropriate basis functions (generally orthogonal polynomials) and the respective expansion coefficients are obtained via collocation equations. The main advantage of these methods is that they simultaneously take into account all available information, rather only the information available at a limited number of mesh points. They require more complicated matrix equations than those obtained in finite difference methods. However, the elegance, speed, and accuracy of the spectral methods more than compensates for any such drawbacks. During the course of the monograph, the authors examine the usually rapid convergence of the spectral expansions and the improved accuracy that results when nonequispaced support points are used, in contrast to the equispaced points used in finite difference methods. In particular, they demonstrate the enhanced accuracy obtained in the solutionof integral equations. The monograph includes an informative introduction to old and new computational methods with numerous practical examples, while at the same time pointing out the errors that each of the available algorithms introduces into the specific solution. It is a valuable resource for undergraduate students as an introduction to the field and for graduate students wishing to compare the available computational methods. In addition, the work develops the criteria required for students to select the most suitable method to solve the particular scientific problem that they are confronting.
Barycentric Rational Interpolation and Spectral Methods
Mathematics and the Aesthetic
Modeling Marine Systems
Algorithms, Analysis and Applications
3+1 Formalism in General Relativity
Spectral Methods in Fluid Dynamics

This two-volume reference presents a series of review and research articles on advances in computing, marine physics, and remote sensing and addresses their importance to shallow sea modeling. Intended as a tribute to Dr. Norman Heaps, topics in the book reflect the range and diversity of his work, as well as his influence on international marine science. Topics discussed include numerical techniques, flow in homogeneous sea regions, stratified flows, lake regimes, validation of numerical models, remote sensing as a method to collect oceanographic data at the sea surface, and bottom boundary modeling. Marine scientists actively involved in mathematical modeling and scientists who are interested in using models as tools to gain more insight and understanding of the processes they are observing will find this text useful.
The numerical simulation of steady planar two-dimensional, laminar flow of an incompressible fluid through an abruptly contracting channel using spectral domain decomposition methods is described. The key features of the method are the decomposition of the flow region into a number of rectangular subregions and spectral approximations which are point wise C1 continuous across subregion interfaces. Spectral approximations to the solution are obtained for Reynolds numbers in the range (0, 500). The size of the salient corner vortex decreases as the Reynolds number increases from 0 to around 45. As the Reynolds number is increased further the vortex grows slowly. A vortex is detected downstream of the Reynolds of around 175 that continues to grow as the Reynolds number is increased further. Keywords: Spectral methods, Domain decomposition, Incompressible fluid dynamics.
Since the publication of "Spectral Methods in Fluid Dynamics" 1988, spectral methods have become firmly established as a mainstream tool for scientific and engineering computation. The authors of that book have incorporated into this new edition the many improvements in the algorithms and the theory of spectral methods that have been made since then. This latest book retains the tight integration between the theoretical and practical aspects of spectral methods, and the chapters are enhanced with material on the Galerkin with numerical integration version of spectral methods. The discussion of direct and iterative solution methods is also greatly expanded.
Spectral Methods for Non-Standard Eigenvalue Problems
Spectral Methods
The Chebyshev-Legendre Method: Implementing Legendre Methods on Chebyshev Points
An Introductory Guide to Computational Methods for the Solution of Physics Problems
A Comparison of Numerical Methods for the Rayleigh Equation in Unbounded Domains
On the Boundary Treatment in Spectral Methods for Hyperbolic Systems

Mathematics of Computing -- Numerical Analysis.
Spectral methods are well-suited to solve problems modeled by time-dependent partial differential equations: they are fast, efficient and accurate and widely used by mathematicians and practitioners. This class-tested 2007 introduction, the first on the subject, is ideal for graduate courses, or self-study. The authors describe the basic theory of spectral methods, allowing the reader to understand the techniques through numerous examples as well as more rigorous developments. They provide a detailed treatment of methods based on Fourier expansions and orthogonal polynomials (including discussions of stability, boundary conditions, filtering, and the extension from the linear to the nonlinear situation). Computational solution techniques for integration in time are dealt with by Runge-Kutta type methods. Several chapters are devoted to material not previously covered in book form, including stability theory for polynomial methods, techniques for problems with discontinuous solutions, round-off errors and the formulation of spectral methods on general grids. These will be especially helpful for practitioners.
This collection of essays explores the ancient affinity between the mathematical and the aesthetic, focusing on fundamental connections between these two modes of reasoning and communicating. From historical, philosophical and psychological perspectives, with particular attention to certain mathematical areas such as geometry and analysis, the authors examine ways in which the aesthetic is ever-present in mathematical thinking and contributes to the growth and value of mathematical knowledge.
Chebyshev Methods and Shock-fitting
Numerical Analysis of Spectral Methods
Spectral and High-order Methods with Applications
A Thesis
Spectral Solution of the Viscous Blunt Body Problem. 2: Multidomain Approximation
Fluid and Structural Mechanics and Beyond

Publisher Description
In the past few years, the differential quadrature method has been applied extensively in engineering. This book, aimed primarily at practising engineers, scientists and graduate students, gives a systematic description of the mathematical fundamentals of differential quadrature and its detailed implementation in solving Helmholtz problems and problems of flow, structure and vibration. Differential quadrature provides a global approach to numerical discretization, which approximates the derivatives by a linear weighted sum of all the functional values in the whole domain. Following the analysis of function approximation and the analysis of a linear vector space, it is shown in the book that the weighting coefficients of the polynomial-based, Fourier expansion-based, and exponential-based differential quadrature methods can be computed explicitly. It is also demonstrated that the polynomial-based differential quadrature method is equivalent to the highest-order finite difference scheme. Furthermore, the relationship between differential quadrature and conventional spectral collocation is analysed. The book contains material on: - Linear Vector Space Analysis and the Approximation of a Function; - Polynomial-, Fourier Expansion- and Exponential-based Differential Quadrature; - Differential Quadrature Weighting Coefficient Matrices; - Solution of Differential Quadrature-resultant Equations; - The Solution of Incompressible Navier-Stokes and Helmholtz Equations; - Structural and Vibrational Analysis Applications; - Generalized Integral Quadrature and its Application in the Solution of Boundary Layer Equations. Three FORTRAN programs for simulation of driven cavity flow, vibration analysis of plate and Helmholtz eigenvalue problems respectively, are appended. These sample programs should give the reader a better understanding of differential quadrature and can easily be modified to solve the readers own engineering problems.
This well-written book explains the theory of spectral methods and their application to the computation of viscous incompressible fluid flow, in clear and elementary terms. With many examples throughout, the work will be useful to those teaching at the graduate level, as well as to researchers working in the area.
Foundations of Computational Mathematics
Chebyshev Polynomials
Spectral Methods for Time-Dependent Problems
Conforming Chebyshev Spectral Collocation Methods for the Solution of Laminar Flow in a Constricted Channel
Evolution to Complex Geometries and Applications to Fluid Dynamics
Spectral Methods in MATLAB
This book provides a thorough guide to the use of numerical methods in energy systems and applications. It presents methods for analysing engineering applications for energy systems, discussing finite difference, finite element, and other advanced numerical methods. Solutions to technical problems relating the application of these methods to energy systems are also thoroughly explored. Readers will discover diverse perspectives of the contributing authors and extensive discussions of issues including: • a wide variety of numerical methods concepts and related energy systems applications;• systems equations and optimization, partial differential equations, and finite difference method;• methods for solving nonlinear equations, special methods, and their mathematical implementation in multi-energy sources;• numerical investigations of electrochemical fields and devices; and• issues related to numerical approaches and optimal integration of energy consumption. This is a highly informative and carefully presented book, providing scientific and academic insight for readers with an interest in numerical methods and energy systems.
Stable and spectrally accurate numerical methods are constructed on arbitrary grids for partial differential equations. These new methods are equivalent to conventional spectral methods but do not rely on specific grid distributions. Specifically we show how to implement Legendre Galerkin, Legendre collocation and Laguerre Galerkin methodology on arbitrary grids. (AN).
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A Review of Spectral Methods
Fundamentals in Single Domains
Bases of Numerical Relativity
Spectral Methods for Partial Differential Equations
Theory and Applications
With Emphasis on Spectral Methods

For the numerical solution of differential equations spectral methods typically give excellent accuracy with relatively few points (small N), but certain numerical issues arise with larger N. This thesis focuses on spectral collocation methods, also known as pseudo-spectral methods, that rely on interpolation at collocation points. A relatively new class of interpolants will be considered, namely the Floater-Hormann family of rational interpolants. These interpolants and their properties will be studied, including their use in differentiation by means of differentiation matrices based on rational interpolants in the barycentric form. Then, consideration will be given to the solution of singularly perturbed boundary value problems through the use of boundary layer resolving coordinate transformations. Finally, coupled systems of singularly perturbed boundary value problems will be investigated, though only with the standard Chebyshev collocation method.
Chebyshev and Fourier Spectral MethodsSecond Revised EditionCourier Corporation
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.
A Chebyshev Collocation Pseudo-spectral Method (CCPSM) for 2-D Thermocapillary Flows
Global Collocation Methods for Approximation and the Solution of Partial Differential Equations
The Chebyshev Polynomials
Spectral Methods on Arbitrary Grids
Spectral Methods for Time Dependent Partial Differential Equations
Spectral Methods for Incompressible Viscous Flow

Nowadays mathematical modeling and numerical simulations play an important role in life and natural science. Numerous researchers are working in developing different methods and techniques to help understand the behavior of very complex systems, from the brain activity with real importance in medicine to the turbulent flows with important applications in physics and engineering. This book presents an overview of some models, methods, and numerical computations that are useful for the applied research scientists and mathematicians, fluid tech engineers, and postgraduate students.
We present a new collocation method for the numerical solution of partial differential equations. This method uses the Chebyshev collocation points, but because of the way the boundary conditions are implemented, has all the advantages of the Legendre methods. In particular L2 estimates can be obtained easily for hyperbolic and parabolic problems. Spectral methods, Collocation, Legendre polynomials, Chebyshev polynomials, Stability.
This book focuses on the constructive and practical aspects of spectral methods. It rigorously examines the most important qualities as well as drawbacks of spectral methods in the context of numerical methods devoted to solve non-standard eigenvalue problems. In addition, the book also considers some nonlinear singularly perturbed boundary value problems along with eigenproblems obtained by their linearization around constant solutions. The book is mathematical, poising problems in their proper function spaces, but its emphasis is on algorithms and practical difficulties. The range of applications is quite large. High order eigenvalue problems are frequently beset with numerical ill conditioning problems. The book describes a wide variety of successful modifications to standard algorithms that greatly mitigate these problems. In addition, the book makes heavy use of the concept of pseudospectrum, which is highly relevant to understanding when disaster is imminent in solving eigenvalue problems. It also envisions two classes of applications, the stability of some elastic structures and the hydrodynamic stability of some parallel shear flows. This book is an ideal reference text for professionals (researchers) in applied mathematics, computational physics and engineering. It will be very useful to numerically sophisticated engineers, physicists and chemists. The book can also be used as a textbook in review courses such as numerical analysis, computational methods in various engineering branches or physics and computational methods in analysis.
New Approaches to an Ancient Affinity
A Practical Guide to Pseudospectral Methods
Differential Quadrature and Its Application in Engineering
A Collocation Spectral Method for High Reynolds Number Flow
Spectral Collocation Methods
From Brain Imaging to Turbulent Flows
Collection of papers by leading researchers in computational mathematics, suitable for graduate students and researchers.
This graduate-level, course-based text is devoted to the 3+1 formalism of general relativity, which also constitutes the theoretical foundations of numerical relativity. The book starts by establishing the mathematical background (differential geometry, hypersurfaces embedded in space-time, foliation of space-time by a family of space-like hypersurfaces), and then turns to the 3+1 decomposition of the Einstein equations, giving rise to the Cau
problem with constraints, which constitutes the core of 3+1 formalism. The ADM Hamiltonian formulation of general relativity is also introduced at this stage. Finally, the decomposition of the matter and electromagnetic field equations is presented, focusing on the astrophysically relevant cases of a perfect fluid and a perfect conductor (ideal magnetohydrodynamics). The second part of the book introduces more advanced topics: the conform
transformation of the 3-metric on each hypersurface and the corresponding rewriting of the 3+1 Einstein equations, the Isenberg-Wilson-Mathews approximation to general relativity, global quantities associated with asymptotic flatness (ADM mass, linear and angular momentum) and with symmetries (Komar mass and angular momentum). In the last part, the initial data problem is studied, the choice of spacetime coordinates within the 3+1
framework is discussed and various schemes for the time integration of the 3+1 Einstein equations are reviewed. The prerequisites are those of a basic general relativity course with calculations and derivations presented in detail, making this text complete and self-contained. Numerical techniques are not covered in this book.
We present steady solutions of high speed viscous flows over blunt bodies using a multidomain Chebyshev spectral collocation method. The region within the shock layer is divided into subdomains so that internal layers can be well-resolved. In the interiors of the subdomains, the solution is approximated by Chebyshev collocation. At interfaces between subdomains, the advective terms are upwinded and the viscous terms are treated by a
method. The method is applied to five flows the Mach number range 5-25 and Reynolds number range 2,000 - 83,000, based on nose radius. Results are compared to experimental data and to a finite difference result.
Volume II
Chebyshev and Fourier Spectral Methods
Preconditioning for First-order Spectral Discretization
A Chebyshev spectral solver for the linear Helmholtz equation is presented. The solver is based on the Chebyshev-collocation method. It works for both constant and variable coefficients under general inhomogeneous boundary conditions. If the Helmholtz equation has a constant co-efficient, the method obtains a solution directly. This gives rise to a relatively stable solver for the Helmholtz equation, which is suitable to the simulation of high-Reynolds number (Re) flow. As an illustrative example we show a simulation of the 2D Re = 10,000 drive cavity, whereby we demonstrate the unsteady, time dependent nature of this flow.
This is a book about spectral methods for partial differential equations: when to use them, how to implement them, and what can be learned from their of spectral methods has evolved rigorous theory. The computational side vigorously since the early 1970s, especially in computationally intensive of the more spectacular applications are applications in fluid dynamics. Some of the power of these discussed here, first in general terms as examples of the methods have been methods and later in great detail after the specifics covered. This book pays special attention to those algorithmic details which are essential to successful implementation of spectral methods. The focus is on algorithms for fluid dynamical problems in transition, turbulence, and aero dynamics. This book does not address specific applications in meteorology, partly because of the lack of experience of the authors in this field and partly because of the coverage provided by Haltiner and Williams (1980). The success of spectral methods in practical computations has led to an increasing interest in their theoretical aspects, especially since the mid-1970s.
Although the theory does not yet cover the complete spectrum of applications, the analytical techniques which have been developed in recent years have facilitated the examination of an increasing number of problems of practical interest. In this book we present a unified theory of the mathematical analysis of spectral methods and apply it to many of the algorithms in current use.