Numerical Computation of Spectral Solutions for Sturm-Liouville Eigenvalue Problems

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Abstract. This paper focuses on the study of Sturm-Liouville eigenvalue problems. In the classical Chebyshev collocation method, the Sturm-Liouville problem is discretized to a generalized eigenvalue problem where the functions represent interpolants in suitably rescaled Chebyshev points. We are concerned with the computation of high-order eigenvalues of Sturm-Liouville problems using an effective method of discretization based on the Chebfun software algorithms with domain truncation. We solve some numerical Sturm-Liouville eigenvalue problems and demonstrate the efficiency of computations.

1. Introduction

The Sturm–Liouville problem arises in many applied mathematics, science, physics and engineering areas. Many biological, chemical and physical problems are described by using models based on Sturm–Liouville equations. For example, problems with cylindrical symmetry, diffraction problems (astronomy) resolving power of optical instruments and heavy chains. In quantum mechanics, the solutions of the radial Schrödinger equation describe the eigenvalues of the Sturm-Liouville problem.

These solutions also define the bound state energies of the non-relativistic hydrogen atom. For more applications, see [1], [2] and [3].

In this paper, we consider the Sturm-Liouville problem

$$-\frac{d}{dx}[p(x)\frac{d}{dx}]y + q(x)y = \lambda w(x)y, \ a \le x \le b, \tag{1.1}$$

$$c_a y(a) + d_a y'(a) = 0, \tag{1.2}$$

Numerical Solution Of Sturm Liouville Problems

Uri M. Ascher,Robert M. M. Mattheij,Robert D. Russell

Numerical Solution Of Sturm Liouville Problems:

Numerical Solution of Sturm-Liouville Problems John Derwent Pryce,1993 Sturm Liouville problems SLPs an applied mathematics tool developed in the nineteenth century and a driving force of pure mathematics in the early twentieth century became of vital interest to physicists with the advent of Schrodinger s equations Today s fascinating variety of SL related computations reflects this diverse historical background This book was written for scientists and engineers who desire an introduction to simple SLPs their limitations the algorithms that overcome these limitations and available software Numerical analysts seeking a reference on good SLP methods theory implementation and performance will also want to own a copy of this book Treatments of the underlying mathematical theories and numerous helpful problems round out this superb new volume *Sturm-Liouville Problems* Ronald B. Guenther,John W Lee,2018-10-25 Sturm Liouville problems arise naturally in solving technical problems in engineering physics and more recently in biology and the social sciences These problems lead to eigenvalue problems for ordinary and partial differential equations Sturm Liouville Problems Theory and Numerical Implementation addresses in a unified way the key issues that must be faced in science and engineering applications when separation of variables variational methods or other considerations lead to Sturm Liouville eigenvalue problems and boundary value problems **Direct and Inverse Sturm-Liouville Problems** Vladislav V. Kravchenko,2020-07-28 This book provides an introduction to the most recent developments in the theory and practice of direct and inverse Sturm Liouville problems on finite and infinite intervals A universal approach for practical solving of direct and inverse spectral and scattering problems is presented based on the notion of transmutation transformation operators and their efficient construction Analytical representations for solutions of Sturm Liouville equations as well as for the integral kernels of the transmutation operators are derived in the form of functional series revealing interesting special features and lending themselves to direct and simple numerical solution of a wide variety of problems The book is written for undergraduate and graduate students as well as for mathematicians physicists and engineers interested in direct and inverse spectral problems *Numerical Solution of the Inverse Sturm-Liouville Problem* Albert Chingkwang Yen,1978 *Numerical Solution of Sturm-Liouville Problems Via Fer Streamers* Alberto Gil Couto Pimentel Ramos,2016 **Numerical Solution of Boundary Value Problems for Ordinary Differential Equations** Uri M. Ascher,Robert M. M. Mattheij,Robert D. Russell,1994-12-01 This book is the most comprehensive up to date account of the popular numerical methods for solving boundary value problems in ordinary differential equations It aims at a thorough understanding of the field by giving an in depth analysis of the numerical methods by using decoupling principles Numerous exercises and real world examples are used throughout to demonstrate the methods and the theory Although first published in 1988 this republication remains the most comprehensive theoretical coverage of the subject matter not available elsewhere in one volume Many problems arising in a wide variety of application areas give rise to mathematical models which form boundary value problems for ordinary differential equations

These problems rarely have a closed form solution and computer simulation is typically used to obtain their approximate solution This book discusses methods to carry out such computer simulations in a robust efficient and reliable manner   <u>An Introduction to Numerical Analysis</u> Endre Süli,David F. Mayers,2003-08-28 Numerical analysis provides the theoretical foundation for the numerical algorithms we rely on to solve a multitude of computational problems in science Based on a successful course at Oxford University this book covers a wide range of such problems ranging from the approximation of functions and integrals to the approximate solution of algebraic transcendental differential and integral equations Throughout the book particular attention is paid to the essential qualities of a numerical algorithm stability accuracy reliability and efficiency The authors go further than simply providing recipes for solving computational problems They carefully analyse the reasons why methods might fail to give accurate answers or why one method might return an answer in seconds while another would take billions of years This book is ideal as a text for students in the second year of a university mathematics course It combines practicality regarding applications with consistently high standards of rigour **Numerical Method for Sturm-Liouville Problems** Dhiranuch Bunnag,1999   **Computational Techniques And Applications - Proceedings Of The Sixth Biennial Conference** Henry J Gardner,David Singleton,David Stewart,1994-06-28 This volume contains papers on computational mathematics development implementation and application of numerical algorithms the development and application of computational systems and numerical modelling Also featured are reports on applications of advanced computer architectures and innovative visualisation techniques It will be a help for developers and implementors of computational methods who wish to find out more about the work of those applying the technology to problems in engineering and science and vice versa   **Library of Congress Subject Headings** Library of Congress,   **Scientific and Technical Aerospace Reports** ,1988   *Library of Congress Subject Headings* Library of Congress. Cataloging Policy and Support Office,2009   *Numerical Solution of Ordinary Differential Equations* L.F. Shampine,2018-10-24 This new work is an introduction to the numerical solution of the initial value problem for a system of ordinary differential equations The first three chapters are general in nature and chapters 4 through 8 derive the basic numerical methods prove their convergence study their stability and consider how to implement them effectively The book focuses on the most important methods in practice and develops them fully uses examples throughout and emphasizes practical problem solving methods   *Computational Methods in Physics* Simon Širca,Martin Horvat,2025-04-01 This textbook provides a compendium of numerical methods to assist physics students and researchers in their daily work It carefully considers error estimates stability and convergence issues the choice of optimal methods and techniques to increase program execution speeds The book supplies numerous examples throughout the chapters that are concluded by more comprehensive problems with a strong physics background Instead of uncritically employing modern black box tools the readers are encouraged to develop a more ponderous and skeptical approach This revised and expanded edition now

includes a new chapter on numerical integration and stable differentiation as well as fresh material on optimal filtering integration of gravitational many body problems computation of Poincar maps regularization of orbits singular Sturm Liouville problems techniques for time evolution and spatial treatment of semi infinite domains in spectral methods and phase retrieval It also brings updated discussions of algebraic problems involving sparse matrices and of high resolution schemes for partial differential equations **Geometric Analysis of Nonlinear Partial Differential Equations** Valentin Lychagin,Joseph Krasilshchik,2021-09-03 This book contains a collection of twelve papers that reflect the state of the art of nonlinear differential equations in modern geometrical theory It comprises miscellaneous topics of the local and nonlocal geometry of differential equations and the applications of the corresponding methods in hydrodynamics symplectic geometry optimal investment theory etc The contents will be useful for all the readers whose professional interests are related to nonlinear PDEs and differential geometry both in theoretical and applied aspects **Ordinary Differential Equations and Integral Equations** C.T.H. Baker,G. Monegato,G. vanden Berghe,2001-07-04 homepage sac cam na2000 index html7 Volume Set now available at special set price This volume contains contributions in the area of differential equations and integral equations Many numerical methods have arisen in response to the need to solve real life problems in applied mathematics in particular problems that do not have a closed form solution Contributions on both initial value problems and boundary value problems in ordinary differential equations appear in this volume Numerical methods for initial value problems in ordinary differential equations fall naturally into two classes those which use one starting value at each step one step methods and those which are based on several values of the solution multistep methods John Butcher has supplied an expert s perspective of the development of numerical methods for ordinary differential equations in the 20th century Rob Corless and Lawrence Shampine talk about established technology namely software for initial value problems using Runge Kutta and Rosenbrock methods with interpolants to fill in the solution between mesh points but the slant is new based on the question How should such software integrate into the current generation of Problem Solving Environments Natalia Borovykh and Marc Spijker study the problem of establishing upper bounds for the norm of the nth power of square matrices The dynamical system viewpoint has been of great benefit to ODE theory and numerical methods Related is the study of chaotic behaviour Willy Govaerts discusses the numerical methods for the computation and continuation of equilibria and bifurcation points of equilibria of dynamical systems Arieh Iserles and Antonella Zanna survey the construction of Runge Kutta methods which preserve algebraic invariant functions Valeria Antohe and Ian Gladwell present numerical experiments on solving a Hamiltonian system of H non and Heiles with a symplectic and a nonsymplectic method with a variety of precisions and initial conditions Stiff differential equations first became recognized as special during the 1950s In 1963 two seminal publications laid to the foundations for later development Dahlquist s paper on A stable multistep methods and Butcher s first paper on implicit Runge Kutta methods Ernst Hairer and Gerhard Wanner deliver a survey which retraces the discovery of the order

stars as well as the principal achievements obtained by that theory Guido Vanden Berghe Hans De Meyer Marnix Van Daele and Tanja Van Hecke construct exponentially fitted Runge Kutta methods with s stages Differential algebraic equations arise in control in modelling of mechanical systems and in many other fields Jeff Cash describes a fairly recent class of formulae for the numerical solution of initial value problems for stiff and differential algebraic systems Shengtai Li and Linda Petzold describe methods and software for sensitivity analysis of solutions of DAE initial value problems Again in the area of differential algebraic systems Neil Biehn John Betts Stephen Campbell and William Huffman present current work on mesh adaptation for DAE two point boundary value problems Contrasting approaches to the question of how good an approximation is as a solution of a given equation involve i attempting to estimate the actual error i e the difference between the true and the approximate solutions and ii attempting to estimate the defect the amount by which the approximation fails to satisfy the given equation and any side conditions The paper by Wayne Enright on defect control relates to carefully analyzed techniques that have been proposed both for ordinary differential equations and for delay differential equations in which an attempt is made to control an estimate of the size of the defect Many phenomena incorporate noise and the numerical solution of stochastic differential equations has developed as a relatively new item of study in the area Keven Burrage Pamela Burrage and Taketomo Mitsui review the way numerical methods for solving stochastic differential equations SDE s are constructed One of the more recent areas to attract scrutiny has been the area of differential equations with after effect retarded delay or neutral delay differential equations and in this volume we include a number of papers on evolutionary problems in this area The paper of Genna Bocharov and Fathalla Rihan conveys the importance in mathematical biology of models using retarded differential equations The contribution by Christopher Baker is intended to convey much of the background necessary for the application of numerical methods and includes some original results on stability and on the solution of approximating equations Alfredo Bellen Nicola Guglielmi and Marino Zennaro contribute to the analysis of stability of numerical solutions of nonlinear neutral differential equations Koen Engelborghs Tatyana Luzyanina Dirk Roose Neville Ford and Volker Wulf consider the numerics of bifurcation in delay differential equations Evelyn Buckwar contributes a paper indicating the construction and analysis of a numerical strategy for stochastic delay differential equations SDDEs This volume contains contributions on both Volterra and Fredholm type integral equations Christopher Baker responded to a late challenge to craft a review of the theory of the basic numerics of Volterra integral and integro differential equations Simon Shaw and John Whiteman discuss Galerkin methods for a type of Volterra integral equation that arises in modelling viscoelasticity A subclass of boundary value problems for ordinary differential equation comprises eigenvalue problems such as Sturm Liouville problems SLP and Schr dinger equations Liviu Ixaru describes the advances made over the last three decades in the field of piecewise perturbation methods for the numerical solution of Sturm Liouville problems in general and systems of Schr dinger equations in particular Alan Andrew surveys the asymptotic correction method for regular Sturm

Liouville problems Leon Greenberg and Marco Marletta survey methods for higher order Sturm Liouville problems R Moore in the 1960s first showed the feasibility of validated solutions of differential equations that is of computing guaranteed enclosures of solutions Boundary integral equations Numerical solution of integral equations associated with boundary value problems has experienced continuing interest Peter Junghanns and Bernd Silbermann present a selection of modern results concerning the numerical analysis of one dimensional Cauchy singular integral equations in particular the stability of operator sequences associated with different projection methods Johannes Elschner and Ivan Graham summarize the most important results achieved in the last years about the numerical solution of one dimensional integral equations of Mellin type of means of projection methods and in particular by collocation methods A survey of results on quadrature methods for solving boundary integral equations is presented by Andreas Rathsfeld Wolfgang Hackbusch and Boris Khoromski present a novel approach for a very efficient treatment of integral operators Ernst Stephan examines multilevel methods for the h p and hp versions of the boundary element method including pre conditioning techniques George Hsiao Olaf Steinbach and Wolfgang Wendland analyze various boundary element methods employed in local discretization schemes **Advanced Engineering Mathematics with MATLAB** Dean G. Duffy,2016-12-12 Advanced Engineering Mathematics with MATLAB Fourth Edition builds upon three successful previous editions It is written for today s STEM science technology engineering and mathematics student Three assumptions under lie its structure 1 All students need a firm grasp of the traditional disciplines of ordinary and partial differential equations vector calculus and linear algebra 2 The modern student must have a strong foundation in transform methods because they provide the mathematical basis for electrical and communication studies 3 The biological revolution requires an understanding of stochastic random processes The chapter on Complex Variables positioned as the first chapter in previous editions is now moved to Chapter 10 The author employs MATLAB to reinforce concepts and solve problems that require heavy computation Along with several updates and changes from the third edition the text continues to evolve to meet the needs of today s instructors and students Features Complex Variables formerly Chapter 1 is now Chapter 10 A new Chapter 18 It s Stochastic Calculus Implements numerical methods using MATLAB updated and expanded Takes into account the increasing use of probabilistic methods in engineering and the physical sciences Includes many updated examples exercises and projects drawn from the scientific and engineering literature Draws on the author s many years of experience as a practitioner and instructor Gives answers to odd numbered problems in the back of the book Offers downloadable MATLAB code at www crcpress com **Handbook of Differential Equations** Daniel Zwillinger,Vladimir Dobrushkin,2021-12-30 Through the previous three editions Handbook of Differential Equations has proven an invaluable reference for anyone working within the field of mathematics including academics students scientists and professional engineers The book is a compilation of methods for solving and approximating differential equations These include the most widely applicable methods for solving and approximating differential equations as well as numerous

methods Topics include methods for ordinary differential equations partial differential equations stochastic differential equations and systems of such equations Included for nearly every method are The types of equations to which the method is applicable The idea behind the method The procedure for carrying out the method At least one simple example of the method Any cautions that should be exercised Notes for more advanced users The fourth edition includes corrections many supplied by readers as well as many new methods and techniques These new and corrected entries make necessary improvements in this edition   Inverse Eigenvalue Problems Moody Chu,Gene Golub,2005-06-16 Inverse eigenvalue problems arise in a remarkable variety of applications and associated with any inverse eigenvalue problem are two fundamental questions the theoretical issue of solvability and the practical issue of computability Both questions are difficult and challenging In this text the authors discuss the fundamental questions some known results many applications mathematical properties a variety of numerical techniques as well as several open problems This is the first book in the authoritative Numerical Mathematics and Scientific Computation series to cover numerical linear algebra a broad area of numerical analysis Authored by two world renowned researchers the book is aimed at graduates and researchers in applied mathematics engineering and computer science and makes an ideal graduate text   Computational Techniques And Applications: Ctac 95 - Proceedings Of The Seventh Biennial Conference Robert L May,Alan K Easton,1996-08-30 This proceedings contains seven invited papers and 100 contributed papers The topics covered range from studies of theoretical aspects of computational methods through to simulations of large scale industrial processes with an emphasis on the efficient use of computers to solve practical problems Developers and users of computational techniques who wish to keep up with recent developments in the application of modern computational technology to problems in science and engineering will find much of interest in this volume

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