

3 Numerical Solution of Differential Equations

One of the simplest mathematical models known in epidemiology is so-called SIRD model¹. It is defined by the following system of differential equations

$$\begin{cases} S'(t) = -\frac{\beta}{N}I(t)S(t) \\ I'(t) = \frac{\beta}{N}I(t)S(t) - \alpha I(t) - \gamma I(t) \\ R'(t) = \alpha I(t) \\ D'(t) = \gamma I(t) \end{cases}$$

where $S(t)$ denotes the number of susceptible individuals, $I(t)$ denotes the number of infected individuals, $R(t)$ denotes the number of recovered individuals, $D(t)$ denotes the number of deceased individuals, β is the infection rate, α is the recovery rate, γ is the mortality rate, and $N = S + I + R + D$. Assume that $S(0) = 997$, $I(0) = 3$, $R(0) = 0$, $D(0) = 0$, $\beta = 0.4$, $\alpha = 0.035$, $\gamma = 0.005$, and $t \in [0, 150]$.

- Use Matlab ODE solver *ode45* to calculate the numerical solution of SIRD model with given parameters and initial conditions. Plot in one frame the numerical solutions of $S(t)$, $I(t)$, $R(t)$, and $D(t)$ against time. What do you observe from the plots and how do you interpret the dynamics of the system?
- Write the code implementing the third order Runge-Kutta method (*RK3*) given by the following Butcher table:

0			
1/2	1/2		
1	-1	2	
	1/6	2/3	1/6

Use *RK3* method with stepsize $\tau = 10^{-3}$ to find the numerical solution of SIRD model with given parameters and initial conditions. Plot in one frame the numerical solutions of $S(t)$, $I(t)$, $R(t)$, and $D(t)$ against time. Make a qualitative comparison with the results obtained with *ode45* solver.

Numerical Solution Of Differential Equat

**Kendall Atkinson, Weimin Han, David E.
Stewart**



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Numerical Solution Of Ordinary And Partial Differential Equations, The (3rd Edition) Granville

Sewell, 2014-12-16 This book presents methods for the computational solution of differential equations both ordinary and partial time dependent and steady state Finite difference methods are introduced and analyzed in the first four chapters and finite element methods are studied in chapter five A very general purpose and widely used finite element program PDE2D which implements many of the methods studied in the earlier chapters is presented and documented in Appendix A The book contains the relevant theory and error analysis for most of the methods studied but also emphasizes the practical aspects involved in implementing the methods Students using this book will actually see and write programs FORTRAN or MATLAB for solving ordinary and partial differential equations using both finite differences and finite elements In addition they will be able to solve very difficult partial differential equations using the software PDE2D presented in Appendix A PDE2D solves very general steady state time dependent and eigenvalue PDE systems in 1D intervals general 2D regions and a wide range of simple 3D regions The Windows version of PDE2D comes free with every purchase of this book More information at www.pde2d.com contact

Numerical Solution of Differential Equations Zhilin Li, Zhonghua Qiao, Tao Tang, 2017-11-30 This introduction to finite difference and finite element methods is aimed at graduate students who need to solve differential equations The prerequisites are few basic calculus linear algebra and ODEs and so the book will be accessible and useful to readers from a range of disciplines across science and engineering Part I begins with finite difference methods Finite element methods are then introduced in Part II In each part the authors begin with a comprehensive discussion of one dimensional problems before proceeding to consider two or higher dimensions An emphasis is placed on numerical algorithms related mathematical theory and essential details in the implementation while some useful packages are also introduced The authors also provide well tested MATLAB codes all available online Numerical Solution of Differential Equations William Edmund Milne, 1970 Numerical Solution of Ordinary Differential Equations Kendall Atkinson, Weimin Han, David E. Stewart, 2011-10-24

A concise introduction to numerical methods and the mathematical framework needed to understand their performance Numerical Solution of Ordinary Differential Equations presents a complete and easy to follow introduction to classical topics in the numerical solution of ordinary differential equations The book's approach not only explains the presented mathematics but also helps readers understand how these numerical methods are used to solve real world problems Unifying perspectives are provided throughout the text bringing together and categorizing different types of problems in order to help readers comprehend the applications of ordinary differential equations In addition the authors' collective academic experience ensures a coherent and accessible discussion of key topics including Euler's method Taylor and Runge Kutta methods General error analysis for multi step methods Stiff differential equations Differential algebraic equations Two point boundary value problems Volterra integral equations Each chapter features problem sets that enable

readers to test and build their knowledge of the presented methods and a related Web site features MATLAB programs that facilitate the exploration of numerical methods in greater depth Detailed references outline additional literature on both analytical and numerical aspects of ordinary differential equations for further exploration of individual topics Numerical Solution of Ordinary Differential Equations is an excellent textbook for courses on the numerical solution of differential equations at the upper undergraduate and beginning graduate levels It also serves as a valuable reference for researchers in the fields of mathematics and engineering

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Pachis, 2016-04-01 Numerical methods for ordinary differential equations are methods used to find numerical approximations to the solutions of ordinary differential equations ODEs Their use is also known as numerical integration although this term is sometimes taken to mean the computation of integrals An ordinary differential equation or ODE is a differential equation containing one or more functions of one independent variable and its derivatives The term ordinary is used in contrast with the term partial differential equation which may be with respect to more than one independent variable Ordinary differential equations are ubiquitous in science and engineering in geometry and mechanics from the first examples onwards Newton Leibniz Euler Lagrange in chemical reaction kinetics molecular dynamics electronic circuits population dynamics and many more application areas They also arise after semi discretization in space in the numerical treatment of time dependent partial differential equations which are even more impressively omnipresent in our technologically developed and financially controlled world The book Numerical Solution of Ordinary Differential Equations offers a complete and easy to follow introduction to classical topics in the numerical solution of ordinary differential equations The book's approach not only explains the presented mathematics but also helps readers understand how these numerical methods are used to solve real world problems

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Numerical Methods for Differential Equations J.R. Dormand, 2018-05-04 With emphasis on modern techniques Numerical Methods for Differential Equations A Computational Approach covers the development and application of methods for the numerical solution of ordinary differential equations Some of the methods are extended to cover partial differential equations All techniques covered in the text are on a program disk included with the book and are written in Fortran 90 These programs are ideal for students researchers and practitioners because they allow for straightforward application of the numerical methods described in the text The code is easily modified to solve new systems of equations Numerical Methods for Differential Equations A Computational Approach also contains a reliable and inexpensive global error code for those interested in global error estimation This is a valuable text for students who will find the derivations of the numerical methods extremely helpful and the programs themselves easy to use It is also an excellent reference and source of software for researchers and practitioners who need computer solutions to differential equations

A First Course in the Numerical Analysis of Differential Equations Arieh Iserles, 2008-11-27 Numerical analysis presents different faces to the world For mathematicians it is a bona fide mathematical theory with an applicable flavour For scientists and engineers it is a practical applied subject part of the standard repertoire of modelling techniques For computer scientists it is a theory on the interplay of computer architecture and algorithms for real number calculations The tension between these standpoints is the driving force of this book which presents a rigorous account of the fundamentals of numerical analysis of both ordinary and partial differential equations The exposition maintains a balance between theoretical algorithmic and applied aspects This second edition has been extensively updated and includes new chapters on emerging subject areas geometric numerical integration spectral methods and conjugate gradients Other topics covered include multistep and Runge Kutta methods finite difference and finite elements techniques for the Poisson equation and a variety of algorithms to solve large sparse algebraic systems

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

Introduction to the Numerical Solution of Differential Equations Douglas Quinney, 1987-06-29 The Numerical Solution of Differential-Algebraic Systems by Runge-Kutta Methods Ernst Hairer, Christian Lubich, Michel Roche, 2006-11-14 The term differential algebraic equation was coined to comprise

differential equations with constraints differential equations on manifolds and singular implicit differential equations Such problems arise in a variety of applications e g constrained mechanical systems fluid dynamics chemical reaction kinetics simulation of electrical networks and control engineering From a more theoretical viewpoint the study of differential algebraic problems gives insight into the behaviour of numerical methods for stiff ordinary differential equations These lecture notes provide a self contained and comprehensive treatment of the numerical solution of differential algebraic systems using Runge Kutta methods and also extrapolation methods Readers are expected to have a background in the numerical treatment of ordinary differential equations The subject is treated in its various aspects ranging from the theory through the analysis to implementation and applications

Introduction to Numerical Methods in Differential Equations Mark H. Holmes, 2007-04-05 The title gives a reasonable first order approximation to what this book is about To explain why let's start with the expression differential equations These are essential in science and engineering because the laws of nature typically result in equations relating spatial and temporal changes in one or more variables

To develop an understanding of what is involved in finding solutions the book begins with problems involving derivatives for only one independent variable and these give rise to ordinary differential equations Specifically the first chapter considers initial value problems time derivatives and the second concentrates on boundary value problems space derivatives In the succeeding four chapters problems involving both time and space derivatives partial differential equations are investigated This brings us to the next expression in the title numerical methods This is a book about how to transform differential equations into problems that can be solved using a computer The fact is that computers are only able to solve discrete problems and generally do this using finite precision arithmetic What this means is that in deriving and then using a numerical algorithm the correctness of the discrete approximation must be considered as must the consequences of round off error in using floating point arithmetic to calculate the answer One of the interesting aspects of the subject is that what appears to be an obviously correct numerical method can result in complete failure Consequently although the book concentrates on the derivation and use of numerical methods the theoretical underpinnings are also presented and used in the development

Numerical Solution of Differential Equations Mahinder Kumar Jain, 1979

Partial Differential Equations J. Necas, 2018-05-04 As a satellite conference of the 1998 International Mathematical Congress and part of the celebration of the 650th anniversary of Charles University the Partial Differential Equations Theory and Numerical Solution conference was held in Prague in August 1998 With its rich scientific program the conference provided an opportunity for almost 200 participants to gather and discuss emerging directions and recent developments in partial differential equations PDEs This volume comprises the Proceedings of that conference In it leading specialists in partial differential equations calculus of variations and numerical analysis present up to date results applications and advances in numerical methods in their fields Conference organizers chose the contributors to bring together the scientists best able to present a complex view of problems starting from the

modeling passing through the mathematical treatment and ending with numerical realization The applications discussed include fluid dynamics semiconductor technology image analysis motion analysis and optimal control The importance and quantity of research carried out around the world in this field makes it imperative for researchers applied mathematicians physicists and engineers to keep up with the latest developments With its panel of international contributors and survey of the recent ramifications of theory applications and numerical methods *Partial Differential Equations Theory and Numerical Solution* provides a convenient means to that end

Numerical Solution of Stochastic Differential Equations Peter E. Kloeden, Eckhard Platen, 1992 The numerical analysis of stochastic differential equations SDEs differs significantly from that of ordinary differential equations This book provides an easily accessible introduction to SDEs their applications and the numerical methods to solve such equations From the reviews The authors draw upon their own research and experiences in obviously many disciplines considerable time has obviously been spent writing this in the simplest language possible ZAMP

Numerical Solution of Partial Differential Equations K. W. Morton, D. F. Mayers, 1994-10-20 Partial differential equations are the chief means of providing mathematical models in science engineering and other fields Generally these models must be solved numerically This book provides a concise introduction to standard numerical techniques ones chosen on the basis of their general utility for practical problems The authors emphasise finite difference methods for simple examples of parabolic hyperbolic and elliptic equations finite element finite volume and spectral methods are discussed briefly to see how they relate to the main theme Stability is treated clearly and rigorously using maximum principles energy methods and discrete Fourier analysis Methods are described in detail for simple problems accompanied by typical graphical results A key feature is the thorough analysis of the properties of these methods Plenty of examples and exercises of varying difficulty are supplied The book is based on the extensive teaching experience of the authors who are also well known for their work on practical and theoretical aspects of numerical analysis It will be an excellent choice for students and teachers in mathematics engineering and computer science departments seeking a concise introduction to the subject

Numerical Solution of Ordinary Differential Equations, 1971-03-31 In this book we study theoretical and practical aspects of computing methods for mathematical modelling of nonlinear systems A number of computing techniques are considered such as methods of operator approximation with any given accuracy operator interpolation techniques including a non Lagrange interpolation methods of system representation subject to constraints associated with concepts of causality memory and stationarity methods of system representation with an accuracy that is the best within a given class of models methods of covariance matrix estimation methods for low rank matrix approximations hybrid methods based on a combination of iterative procedures and best operator approximation and methods for information compression and filtering under condition that a filter model should satisfy restrictions associated with causality and different types of memory As a result the book represents a blend of new methods in general computational analysis and specific but also generic techniques for study of

systems theory and its particular branches such as optimal filtering and information compression Best operator approximation Non Lagrange interpolation Generic Karhunen Loeve transform Generalised low rank matrix approximation Optimal data compression Optimal nonlinear filtering *Numerical Analysis of Ordinary and Delay Differential Equations* Taketomo Mitsui, Guang-Da Hu, 2023-05-23 This book serves as a concise textbook for students in an advanced undergraduate or first year graduate course in various disciplines such as applied mathematics control and engineering who want to understand the modern standard of numerical methods of ordinary and delay differential equations Experts in the same fields can also learn about the recent developments in numerical analysis of such differential systems Ordinary differential equations ODEs provide a strong mathematical tool to express a wide variety of phenomena in science and engineering Along with its own significance one of the powerful directions toward which ODEs extend is to incorporate an unknown function with delayed argument This is called delay differential equations DDEs which often appear in mathematical modelling of biology demography epidemiology and control theory In some cases the solution of a differential equation can be obtained by algebraic combinations of known mathematical functions In many practical cases however such a solution is quite difficult or unavailable and numerical approximations are called for Modern development of computers accelerates the situation and moreover launches more possibilities of numerical means Henceforth the knowledge and expertise of the numerical solution of differential equations becomes a requirement in broad areas of science and engineering One might think that a well organized software package such as MATLAB serves much the same solution In a sense this is true but it must be kept in mind that blind employment of software packages misleads the user The gist of numerical solution of differential equations still must be learned The present book is intended to provide the essence of numerical solutions of ordinary differential equations as well as of delay differential equations Particularly the authors noted that there are still few concise textbooks of delay differential equations and then they set about filling the gap through descriptions as transparent as possible Major algorithms of numerical solution are clearly described in this book The stability of solutions of ODEs and DDEs is crucial as well The book introduces the asymptotic stability of analytical and numerical solutions and provides a practical way to analyze their stability by employing a theory of complex functions *Numerical Analysis of Systems of Ordinary and Stochastic Differential Equations* Sergej S. Artemiev, Tatjana A. Averina, 1997 This book deals with numerical analysis of systems of both ordinary and stochastic differential equations The first chapter is devoted to numerical solution problems of the Cauchy problem for stiff ordinary differential equation ODE systems by Rosenbrock type methods RTMs Here general solutions of consistency equations are obtained which lead to the construction of RTMs from the first to the fourth order The second chapter deals with statistical simulation problems of the solution of the Cauchy problem for stochastic differential equation SDE systems The mean square convergence theorem is considered as well as Taylor expansions of numerical solutions Also included are applications of numerical methods of SDE solutions to partial differential equations and to

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