Numerical Analysis of Dynamical Systems

John Guckenheimer [*]

October 5, 1999

1   Introduction

This paper presents a brief overview of algorithms that aid in the analysis of dynamical systems and their bifurcations. The viewpoint is geometric and the goal is to describe algorithms that reliably compute objects of dynamical significance. Reliability has three facets:

1. the probability that the algorithm returns an answer for different choices of starting data,

2. whether the computed object is qualitatively correct, and

3. the accuracy with which the objects are computed.

Numerical analysis has traditionally concentrated on the third of these topics, but the first two are perhaps more important in numerical studies that seek to delineate the structure of dynamical systems.

This survey concentrates on exposition of fundamental mathematical principles and their application to the numerical analysis of examples. There is a strong interplay between dynamical systems theory and computational analysis of dynamical systems. The theory provides a framework for interpreting numerical observations and foundations for algorithms. Apparent discrepancies between computational output and theoretical expectations point to areas where phenomena have been overlooked in the theory, areas where algorithms produce misleading results, and areas where the relationship between theory and computation is more subtle than anticipated. Several examples of simple systems are used in this article to illustrate seeming differences between computation and theory.

Dynamical Systems And Numerical Analysis

J. Honerkamp

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   Dynamical Systems and Numerical Analysis A. M. Stuart,A. R. Humphries,1998-11-28 The first three chapters contain the elements of the theory of dynamical systems and the numerical solution of initial value problems In the remaining chapters numerical methods are formulated as dynamical systems and the convergence and stability properties of the methods are examined   Modelling and Control of Dynamical Systems: Numerical Implementation in a Behavioral Framework Ricardo Zavala Yoe,2008-05-30 The Behavioral Approach for systems and control deals directly with the solution of the differential equations which represent the system This book reviews this approach and offers new theoretic results The programs and algorithms are MATLAB based   Dynamical Systems and Numerical Analysis Xingtuan Yang,Nan Gui,2016

   Advances in Numerical Analysis William Allan Light,1991   **Numerical Methods for Bifurcations of Dynamical Equilibria** Willy J. F. Govaerts,2000-01-01 Numerical methods for the detection computation and continuation of equilibria and bifurcation points of equilibria of dynamical systems   **Numerical Analysis of Dynamical Systems** John M. Guckenheimer,1999 This paper presents a brief overview of algorithms that aid in the analysis of dynamical systems and their bifurcations   Numerical Analysis of Dynamical Systems Antony R. Humphries,1993   *Dynamical Systems Method and Applications* Alexander G. Ramm,Nguyen S. Hoang,2013-06-07 Demonstrates the application of DSM to solve a broad range of operator equations The dynamical systems method DSM is a powerful computational method for solving operator equations With this book as their guide readers will master the application of DSM to solve a variety of linear and nonlinear problems as well as ill posed and well posed problems The authors offer a clear step by step systematic development of DSM that enables readers to grasp the method s underlying logic and its numerous applications Dynamical Systems Method and Applications begins with a general introduction and then sets forth the scope of DSM in Part One Part Two introduces the discrepancy principle and Part Three offers examples of numerical applications of DSM to solve a broad range of problems in science and engineering Additional featured topics include General nonlinear operator equations Operators satisfying a spectral assumption Newton type methods without inversion of the derivative Numerical problems arising in applications Stable numerical differentiation Stable solution to ill conditioned linear algebraic systems Throughout the chapters the authors employ the use of figures and tables to help readers grasp and apply new concepts Numerical examples offer original theoretical results based on the solution of practical problems involving ill conditioned linear algebraic systems and stable differentiation of noisy data Written by internationally recognized authorities on the topic Dynamical Systems Method and Applications is an excellent book for courses on numerical analysis dynamical systems operator theory and applied mathematics at the graduate level The book also serves as a valuable resource for professionals in the fields of mathematics physics and engineering   *Numerical Analysis of Dynamical Systems* Stanford University. Computer Science Department. Scientific Computing and Computational Mathematics Program,Andrew M. Stuart,1994   Numerical Analysis of Dynamical

Systems with Codimension Two Singularities Joseph Nikolai Páez Chávez,2009 **Numerical Continuation Methods for Dynamical Systems** Bernd Krauskopf,Hinke M. Osinga,Jorge Galan-Vioque,2007-11-06 Path following in combination with boundary value problem solvers has emerged as a continuing and strong influence in the development of dynamical systems theory and its application It is widely acknowledged that the software package AUTO developed by Eusebius J Doedel about thirty years ago and further expanded and developed ever since plays a central role in the brief history of numerical continuation This book has been compiled on the occasion of Sebius Doedel s 60th birthday Bringing together for the first time a large amount of material in a single accessible source it is hoped that the book will become the natural entry point for researchers in diverse disciplines who wish to learn what numerical continuation techniques can achieve The book opens with a foreword by Herbert B Keller and lecture notes by Sebius Doedel himself that introduce the basic concepts of numerical bifurcation analysis The other chapters by leading experts discuss continuation for various types of systems and objects and showcase examples of how numerical bifurcation analysis can be used in concrete applications Topics that are treated include interactive continuation tools higher dimensional continuation the computation of invariant manifolds and continuation techniques for slow fast systems for symmetric Hamiltonian systems for spatially extended systems and for systems with delay Three chapters review physical applications the dynamics of a SQUID global bifurcations in laser systems and dynamics and bifurcations in electronic circuits **Stochastic Dynamical Systems** J. Honerkamp,1993-12-31 **Advances in Numerical Analysis of Nonlinear Dynamical Systems and the Application to Transfer Capability of Power Systems** Alexander Joel Flueck,1996 *Shadowing and Numerical Analysis of Set-valued Dynamical Systems* Janosch Rieger,2009 *Dynamical Systems Method for Solving Nonlinear Operator Equations* Alexander G. Ramm,2006-09-25 Dynamical Systems Method for Solving Nonlinear Operator Equations is of interest to graduate students in functional analysis numerical analysis and ill posed and inverse problems especially The book presents a general method for solving operator equations especially nonlinear and ill posed It requires a fairly modest background and is essentially self contained All the results are proved in the book and some of the background material is also included The results presented are mostly obtained by the author Contains a systematic development of a novel general method the dynamical systems method DSM for solving operator equations especially nonlinear and ill posed Self contained suitable for wide audience Can be used for various courses for graduate students and partly for undergraduates especially for RUE classes Differential Equations Marcelo Viana,José M. Espinar,2021-12-30 This graduate level introduction to ordinary differential equations combines both qualitative and numerical analysis of solutions in line with Poincar s vision for the field over a century ago Taking into account the remarkable development of dynamical systems since then the authors present the core topics that every young mathematician of our time pure and applied alike ought to learn The book features a dynamical perspective that drives the motivating questions the style of exposition and the arguments and proof techniques The text is organized in six

cycles The first cycle deals with the foundational questions of existence and uniqueness of solutions The second introduces the basic tools both theoretical and practical for treating concrete problems The third cycle presents autonomous and non autonomous linear theory Lyapunov stability theory forms the fourth cycle The fifth one deals with the local theory including the Grobman Hartman theorem and the stable manifold theorem The last cycle discusses global issues in the broader setting of differential equations on manifolds culminating in the Poincar Hopf index theorem The book is appropriate for use in a course or for self study The reader is assumed to have a basic knowledge of general topology linear algebra and analysis at the undergraduate level Each chapter ends with a computational experiment a diverse list of exercises and detailed historical biographical and bibliographic notes seeking to help the reader form a clearer view of how the ideas in this field unfolded over time   The Stability of Dynamical Systems J. P. LaSalle,1976-01-01 An introduction to aspects of the theory of dynamial systems based on extensions of Liapunov s direct method The main ideas and structure for the theory are presented for difference equations and for the analogous theory for ordinary differential equations and retarded functional differential equations The latest results on invariance properties for non autonomous time varying systems processes are presented for difference and differential equations   *Numerical Methods for Nonsmooth Dynamical Systems* Vincent Acary,Bernard Brogliato,2008-01-30 This book concerns the numerical simulation of dynamical systems whose trajec ries may not be differentiable everywhere They are named nonsmooth dynamical systems They make an important class of systems rst because of the many app cations in which nonsmooth models are useful secondly because they give rise to new problems in various elds of science Usually nonsmooth dynamical systems are represented as differential inclusions complementarity systems evolution va ational inequalities each of these classes itself being split into several subclasses The book is divided into four parts the rst three parts being sketched in Fig 0 1 The aim of the rst part is to present the main tools from mechanics and applied mathematics which are necessary to understand how nonsmooth dynamical systems may be numerically simulated in a reliable way Many examples illustrate the th retical results and an emphasis is put on mechanical systems as well as on electrical circuits the so called Filippov s systems are also examined in some detail due to their importance in control applications The second and third parts are dedicated to a detailed presentation of the numerical schemes A fourth part is devoted to the presentation of the software platform Siconos This book is not a textbook on merical analysis of nonsmooth systems in the sense that despite the main results of numerical analysis convergence order of consistency etc being presented their proofs are not provided   **Perspectives in Dynamical Systems I — Applications** Jan Awrejcewicz,2024-06-24 This proceedings volume gathers selected peer reviewed papers presented at the Dynamical Systems Theory and Applications International Conference DSTA 2021 held virtually on December 6 9 2021 organized by the Department of Automation Biomechanics and Mechatronics at Lodz University of Technology Poland This volume concentrates on studies on applications while Volume II focuses on numerical and analytical approaches Being a truly

international conference this 16th iteration of DSTA received submissions from authors representing 52 countries The program covered both theoretical and experimental approaches to widely understood dynamical systems including topics devoted to bifurcations and chaos control in dynamical systems asymptotic methods in nonlinear dynamics stability of dynamical systems lumped mass and continuous systems vibrations original numerical methods of vibration analysis nonsmooth systems dynamics in life sciences and bioengineering as well as engineering systems and differential equations DSTA conferences aim to provide a common platform for exchanging new ideas and results of recent research in scientific and technological advances in modern dynamical systems Works contained in this volume can appeal to researchers in the field whether in mathematics or applied sciences and practitioners in myriad industries   Rigorous Numerics in Dynamics Jan Bouwe van den Berg,Jean-Philippe Lessard,2018-07-12 This volume is based on lectures delivered at the 2016 AMS Short Course Rigorous Numerics in Dynamics held January 4 5 2016 in Seattle Washington Nonlinear dynamics shapes the world around us from the harmonious movements of celestial bodies via the swirling motions in fluid flows to the complicated biochemistry in the living cell Mathematically these phenomena are modeled by nonlinear dynamical systems in the form of ODEs PDEs and delay equations The presence of nonlinearities complicates the analysis and the difficulties are even greater for PDEs and delay equations which are naturally defined on infinite dimensional function spaces With the availability of powerful computers and sophisticated software numerical simulations have quickly become the primary tool to study the models However while the pace of progress increases one may ask just how reliable are our computations Even for finite dimensional ODEs this question naturally arises if the system under study is chaotic as small differences in initial conditions such as those due to rounding errors in numerical computations yield wildly diverging outcomes These issues have motivated the development of the field of rigorous numerics in dynamics which draws inspiration from ideas in scientific computing numerical analysis and approximation theory The articles included in this volume present novel techniques for the rigorous study of the dynamics of maps via the Conley index theory periodic orbits of delay differential equations via continuation methods invariant manifolds and connecting orbits the dynamics of models with unknown nonlinearities and bifurcations diagrams

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