Phase Portraits of Control Dynamical Systems*

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UNDOUBTEDLY ONE OF THE most often studied problems in mathematics is to describe and characterize the solutions of a general set of first order nonlinear differential equations. The reason for this interest is perhaps not to investigate whether or not our solar system is stable, but certainly the fact that many concrete physical systems can be modelled as a system of differential equations has vitalized the above question over the years. Today much of the research connected with the study of the equation $\dot{x}(t) = F(x(t), t)$ goes under the title Dynamical Systems Theory, see Abraham and Marsden (1978) and Arnold (1989) as two excellent references in this field. An extremely important part of Dynamical Systems Theory is formed by the so-called qualitative theory, where the interest lies not so much in obtaining explicit solutions of the differential equation but much more in generating answers to a question like: is a specific solution of $\dot{x}(t) = F(x(t), t)$ asymptotically stable or not. The phase portrait of a dynamical system forms another example of such a qualitative analysis. In the phase portrait of $\dot{x}(t) = F(x(t), t)$ a rough sketch of trajectories (solutions of the differential equation) is drawn in the plane—no matter if the system lives on a higher dimensional space; some nice, illustrative examples may be found in, for instance, the above-mentioned references (Abraham and Marsden, 1978; Arnold, 1989). For low-dimensional systems such a phase portrait provides a useful information about the (stability) behavior of solutions of the system.

The book *Phase Portraits of Control Dynamical Systems* forms an attempt to describe a phase portrait of a nonlinear control system $\dot{x}(t) = f(x(t), u(t))$, i.e. a family of differential equations parametrized by the admissible input functions $u(\cdot) \in U$. As in case of a dynamical system without inputs, $\dot{x}(t) = F(x(t), t)$, the phase portrait of a control system gives a rough picture of the behavior of the system.

Phase Portraits of Control Dynamical Systems is an English translation from an originally Russian text of 1984. The book presents in a non-rigorous way an introduction to the geometric representation of nonlinear control systems, or, stated in Soviet style, the phase portraits of differential inclusions $\dot{x}(t) \in \Phi(x(t))$, with Φ a set valued map defined as $\Phi(x) = \{f(x, u) \mid u \in U\}$. The material is presented in 40 sections of 2–5 pages each and is completed with an extensive list of references of mainly Soviet publications. Since it is impossible to summarize each of the 40 sections of *Phase Portraits of Control Dynamical Systems* only a short description of the contents will follow. The book gives a general mathematical introduction to nonlinear control systems described as $\dot{x}(t) = f(x(t), u(t))$ where the controls $u(\cdot)$ belong to a predefined given set U. An essential assumption is that at each point x in the state space the set $\Phi(x)$ forms a convex subset of the tangent space at x. This allows for the—at some places very useful—transition to the corresponding Hamiltonian $H(p, x)$ which is defined as the supremum (maximum) of $p\dot{x}$ where $\dot{x}$ runs over $\Phi(x)$. The basic question that is studied throughout the book is whether or not the control system is controllable or not. Or, more specifically, given the system $\dot{x}(t) = f(x(t), u(t))$ with some set of admissible controls U and an initial state x_0, is it possible to construct for a given endpoint x_e an input function $u(t)$ such that the corresponding solution will reach x_e in a (given) finite time T? Stated differently, is it possible to characterize all points that are reachable from x_0 at time T by means of the admissible controls? This set, which is called the *integral funnel* with vertex x_0, is studied in detail in the text and an attempt to draw a corresponding phase portrait of the system $\dot{x}(t) = f(x(t), u(t))$ is proposed. The main elements in these investigations are the boundaries of the integral funnels. With the aid of this analysis, together with an analysis of invariant and singular manifolds the author is able to provide a phase portrait of low-dimensional systems; typically low means in this context 1, 2 and sometimes 3. In particular some motivating mathematical examples of linear, bilinear and general nonlinear systems on a two-dimensional state space are treated in detail. Apart from the sections concentrating on the controllability problem there are paragraphs devoted to mechanical systems, two-level quantum mechanical systems, backward-time funnels, optimal control and Laplace operators connected with nonlinear systems. At most places the results are presented without rigor; the reader who wants to learn the details has to consult the references.

In the last decades the subject nonlinear control systems has become quite fashionable in the control community, see for instance the preprints of the IFAC World Congress in Tallinn (1990) or Münich (1987) and many other conference proceedings. From this point of view I consider it as extremely useful to have a complete translated text from the Soviet Union in order to see what kind of developments are made there, see also the survey-paper of Vakhrameev and Sarychev (1988) in which over 500 papers on geometric control from East and West are reviewed. As one can see from its contents, the scope of the book is rather limited since the main emphasis lies in the study of the controllability of a nonlinear system, herewith ignoring several other important control problems as for instance feedback stabilization, robustness and decoupling. Also, but this is obviously due to the fact that the original text dates back to 1984, no relation is made with more recent work on local controllability and small-time local controllability, see e.g. the survey of Hermes (1991). Another more serious shortcoming of the book seems the lack of a systematic discussion on nonlinear state feedback, which could have been included without too much difficulty. Within the above-mentioned limitations the book is of interest for the mathematical control engineer. It is not only useful to have an idea of the phase portrait analysis for low-dimensional systems, it could also serve as the starting point for further research. Let me mention one specific issue but it should be noted that there are much more stimulating problems hidden. In the discussion of controllability of a planar bilinear system $\dot{x}(t) = Ax(t) + u(t)Bx(t)$ the author gives on page 153 a complete list of necessary and sufficient conditions for the system's controllability. One should really compare this with a different, but analogous, list given in Bacciotti and Boieri (1991) for the stabilization of this system. Although controllability and stabilizability are for a general bilinear system not equivalent properties it seems that there are for such bilinear systems some interesting connections.

Aside from the above I want to conclude this review of *Phase Portraits of Control Dynamical Systems* with a few critical comments. As stated the book is translated from Russian but its translation is really quite poor. Let me give only one of the very many disturbing examples. A differential inclusion $\dot{x}(t) \in \Phi(x(t))$ is, almost everywhere in the text, called a connection, except in Section 3 where it is correctly phrased as a differential inclusion. Besides the poor translation the text contains numerous errors, that at some places really cause confusion. Apart from this critique I consider this book as a useful text on nonlinear systems and I

Phase Portraits Of Control Dynamical Systems

Bjarne S. Jensen

Phase Portraits Of Control Dynamical Systems:

  Phase Portraits of Control Dynamical Systems A.G. Butkovskiy,2012-12-06   **The Dynamic Systems of Basic Economic Growth Models** Bjarne S. Jensen,2012-02-02 Two central problems in the pure theory of economic growth are analysed in this monograph 1 the dynamic laws governing the economic growth processes 2 the kinematic and geometric properties of the set of solutions to the dynamic systems With allegiance to rigor and the emphasis on the theoretical fundamentals of prototype mathematical growth models the treatise is written in the theorem proof style To keep the exposition orderly and as smooth as possible the economic analysis has been separated from the purely mathematical issues and hence the monograph is organized in two books Regarding the scope and content of the two books an Introduction and Over view has been prepared to offer both motivation and a brief account The introduc tion is especially designed to give a recapitulation of the mathematical theory and results presented in Book II which are used as the unifying mathematical framework in the analysis and exposition of the different economic growth models in Book I Economists would probably prefer to go directly to Book I and proceed by consult ing the mathematical theorems of Book II in confirming the economic theorems in Book I Thereby both the independence and interdependence of the economic and mathematical argumentations are respected   **Fundamentals of Ordinary Differential Equations** Mohit Chatterjee,2025-02-20 Fundamentals of Ordinary Differential Equations is a comprehensive guide designed for students researchers and professionals to master ODE theory and applications We cover essential principles advanced techniques and practical applications providing a well rounded resource for understanding differential equations and their real world impact The book offers a multifaceted approach from basic principles to advanced concepts catering to fields like physics engineering biology and economics Mathematical ideas are broken down with step by step explanations examples and illustrations making complex concepts accessible Real world examples throughout each chapter show how ODEs model and analyze systems in diverse disciplines We also explain numerical methods such as Euler s method Runge Kutta and finite differences equipping readers with computational tools for solving ODEs Advanced topics include bifurcation chaos theory Hamiltonian systems and singular perturbations providing an in depth grasp of ODE topics With chapter summaries exercises glossaries and additional resources Fundamentals of Ordinary Differential Equations is an essential reference for students professionals and practitioners across science and engineering fields   **Estimators for Uncertain Dynamic Systems** A.I. Matasov,1999-01-31 When solving the control and design problems in aerospace and naval engi neering energetics economics biology etc we need to know the state of investigated dynamic processes The presence of inherent uncertainties in the description of these processes and of noises in measurement devices leads to the necessity to construct the estimators for corresponding dynamic systems The estimators recover the required information about system state from mea surement data An attempt to solve the estimation problems in an optimal way results in the formulation of different variational problems

The type and complexity of these variational problems depend on the process model the model of uncertainties and the estimation performance criterion A solution of variational problem determines an optimal estimator Howerever there exist at least two reasons why we use nonoptimal esti mators The first reason is that the numerical algorithms for solving the corresponding variational problems can be very difficult for numerical imple mentation For example the dimension of these algorithms can be very high   **Optimal Control for Mathematical Models of Cancer Therapies** Heinz Schättler,Urszula Ledzewicz,2015-09-15 This book presents applications of geometric optimal control to real life biomedical problems with an emphasis on cancer treatments A number of mathematical models for both classical and novel cancer treatments are presented as optimal control problems with the goal of constructing optimal protocols The power of geometric methods is illustrated with fully worked out complete global solutions to these mathematically challenging problems Elaborate constructions of optimal controls and corresponding system responses provide great examples of applications of the tools of geometric optimal control and the outcomes aid the design of simpler practically realizable suboptimal protocols The book blends mathematical rigor with practically important topics in an easily readable tutorial style Graduate students and researchers in science and engineering particularly biomathematics and more mathematical aspects of biomedical engineering would find this book particularly useful   **Mathematical Methods in Optimization of Differential Systems** Viorel Barbu,2012-12-06 This work is a revised and enlarged edition of a book with the same title published in Romanian by the Publishing House of the Romanian Academy in 1989 It grew out of lecture notes for a graduate course given by the author at the University if Ia i and was initially intended for students and readers primarily interested in applications of optimal control of ordinary differential equations In this vision the book had to contain an elementary description of the Pontryagin maximum principle and a large number of examples and applications from various fields of science The evolution of control science in the last decades has shown that its meth ods and tools are drawn from a large spectrum of mathematical results which go beyond the classical theory of ordinary differential equations and real analy ses Mathematical areas such as functional analysis topology partial differential equations and infinite dimensional dynamical systems geometry played and will continue to play an increasing role in the development of the control sciences On the other hand control problems is a rich source of deep mathematical problems Any presentation of control theory which for the sake of accessibility ignores these facts is incomplete and unable to attain its goals This is the reason we considered necessary to widen the initial perspective of the book and to include a rigorous mathematical treatment of optimal control theory of processes governed by ordi nary differential equations and some typical problems from theory of distributed parameter systems   *CONTROL OF DYNAMIC SYSTEMS* Dr.Abdulsattar Abdullah Hamad, ,Dr.M.Lellis Thivagar,Mr.Ahmed S. Al-Obeidi, ,Dr.Saad Fawzi AL-Azzawi,2022-11-06 In this book we consider some of the most broadly applicable techniques for the analysis of discrete and continuous time dynamical systems The same concept can be used to obtain the phase portrait which is a graphical

description of the dynamics over the entire state space   Convex Functions and Optimization Methods on Riemannian Manifolds C. Udriste,2013-11-11 The object of this book is to present the basic facts of convex functions standard dynamical systems descent numerical algorithms and some computer programs on Riemannian manifolds in a form suitable for applied mathematicians scientists and engineers It contains mathematical information on these subjects and applications distributed in seven chapters whose topics are close to my own areas of research Metric properties of Riemannian manifolds First and second variations of the p energy of a curve Convex functions on Riemannian manifolds Geometric examples of convex functions Flows convexity and energies Semidefinite Hessians and applications Minimization of functions on Riemannian manifolds All the numerical algorithms computer programs and the appendices Riemannian convexity of functions f R R Descent methods on the Poincare plane Descent methods on the sphere Completeness and convexity on Finsler manifolds constitute an attempt to make accesible to all users of this book some basic computational techniques and implementation of geometric structures To further aid the readers this book also contains a part of the folklore about Riemannian geometry convex functions and dynamical systems because it is unfortunately nowhere to be found in the same context existing textbooks on convex functions on Euclidean spaces or on dynamical systems do not mention what happens in Riemannian geometry while the papers dealing with Riemannian manifolds usually avoid discussing elementary facts Usually a convex function on a Riemannian manifold is a real valued function whose restriction to every geodesic arc is convex   *Systems Science* ,1994   **Applications of Differential Equations** Jayant Ramaswamy,2025-02-20 Unlock the power of mathematics with Applications of Differential Equations a comprehensive guide that demystifies this essential tool Our book is crafted for students educators and practitioners offering a deep dive into the theory techniques and real world applications of differential equations across diverse fields including physics engineering biology and economics We start with a solid foundation in the basic concepts making the book accessible to beginners while providing valuable insights for advanced learners Clear explanations and illustrative examples guide readers through the classification of differential equations methods for solving first order equations and techniques for analyzing their behavior Step by step solutions and practical exercises reinforce learning ensuring confidence in tackling a wide range of problems Delving into advanced topics we cover higher order differential equations systems of differential equations and Laplace transforms We emphasize mathematical modeling showcasing how differential equations represent real world phenomena and predict their behavior What sets this book apart is its focus on practical applications Real world examples and case studies illustrate how differential equations model and analyze phenomena such as population dynamics fluid mechanics and electrical circuits This approach bridges theory and practice highlighting the versatility and power of differential equations in addressing challenges and advancing knowledge Designed for a global audience our book ensures accessibility and relevance for readers from diverse backgrounds Whether you re a student educator or practitioner Applications of Differential Equations is your go to resource

for mastering this powerful mathematical tool   Chaos and Fractals C.A. Pickover,1998-08-03 These days computer generated fractal patterns are everywhere from squiggly designs on computer art posters to illustrations in the most serious of physics journals Interest continues to grow among scientists and rather surprisingly artists and designers This book provides visual demonstrations of complicated and beautiful structures that can arise in systems based on simple rules It also presents papers on seemingly paradoxical combinations of randomness and structure in systems of mathematical physical biological electrical chemical and artistic interest Topics include iteration cellular automata bifurcation maps fractals dynamical systems patterns of nature created through simple rules and aesthetic graphics drawn from the universe of mathematics and art Chaos and Fractals is divided into six parts Geometry and Nature Attractors Cellular Automata Gaskets and Koch Curves Mandelbrot Julia and Other Complex Maps Iterated Function Systems and Computer Art Additionally information on the latest practical applications of fractals and on the use of fractals in commercial products such as the antennas and reaction vessels is presented In short fractals are increasingly finding application in practical products where computer graphics and simulations are integral to the design process Each of the six sections has an introduction by the editor including the latest research references and updates in the field This book is enhanced with numerous color illustrations a comprehensive index and the many computer program examples encourage reader involvement
    Foundations of Mathematical Optimization Diethard Ernst Pallaschke,S. Rolewicz,2013-03-14 Many books on optimization consider only finite dimensional spaces This volume is unique in its emphasis the first three chapters develop optimization in spaces without linear structure and the analog of convex analysis is constructed for this case Many new results have been proved specially for this publication In the following chapters optimization in infinite topological and normed vector spaces is considered The novelty consists in using the drop property for weak well posedness of linear problems in Banach spaces and in a unified approach by means of the Dolecki approximation to necessary conditions of optimality The method of reduction of constraints for sufficient conditions of optimality is presented The book contains an introduction to non differentiable and vector optimization Audience This volume will be of interest to mathematicians engineers and economists working in mathematical optimization   Introduction to Nonlinear Oscillations Vladimir I. Nekorkin,2016-05-02 A systematic outline of the basic theory of oscillations combining several tools in a single textbook The author explains fundamental ideas and methods while equally aiming to teach students the techniques of solving specific practical or more complex problems Following an introduction to fundamental notions and concepts of modern nonlinear dynamics the text goes on to set out the basics of stability theory as well as bifurcation theory in one and two dimensional cases Foundations of asymptotic methods and the theory of relaxation oscillations are presented with much attention paid to a method of mappings and its applications With each chapter including exercises and solutions including computer problems this book can be used in courses on oscillation theory for physics and engineering students It also serves as a good reference

for students and scientists in computational neuroscience **Cognitive Systems and the Extended Mind** Robert D. Rupert,2009-08-19 Cognitive Systems and the Extended Mind surveys philosophical issues raised by the situated movement in cognitive science that is the treatment of cognitive phenomena as the joint products of brain body and environment *Mind as Motion* Robert F. Port,Timothy Van Gelder,1995 The first comprehensive presentation of the dynamical approach to cognition It contains a representative sampling of original current research on topics such as perception motor control speech and language decision making and development Recent Developments in Well-Posed Variational Problems Roberto Lucchetti,Julian Revalski,2013-03-09 This volume contains several surveys focused on the ideas of approximate solutions well posedness and stability of problems in scalar and vector optimization game theory and calculus of variations These concepts are of particular interest in many fields of mathematics The idea of stability goes back at least to J Hadamard who introduced it in the setting of differential equations the concept of well posedness for minimum problems is more recent the mid sixties and originates with A N Tykhonov It turns out that there are connections between the two properties in the sense that a well posed problem which at least in principle is easy to solve has a solution set that does not vary too much under perturbation of the data of the problem i e it is stable These themes have been studied in depth for minimum problems and now we have a general picture of the related phenomena in this case But of course the same concepts can be studied in other more complicated situations as e g vector optimization game theory and variational inequalities Let us mention that in several of these new areas there is not even a unique idea of what should be called approximate solution and the latter is at the basis of the definition of well posed problem **Mathematical Techniques of Fractional Order Systems** Ahmad Taher Azar,Ahmed G. Radwan,Sundarapandian Vaidyanathan,2018-06-11 Mathematical Techniques of Fractional Order Systems illustrates advances in linear and nonlinear fractional order systems relating to many interdisciplinary applications including biomedical control circuits electromagnetics and security The book covers the mathematical background and literature survey of fractional order calculus and generalized fractional order circuit theorems from different perspectives in design analysis and realizations nonlinear fractional order circuits and systems the fractional order memristive circuits and systems in design analysis emulators simulation and experimental results It is primarily meant for researchers from academia and industry and for those working in areas such as control engineering electrical engineering computer science and information technology This book is ideal for researchers working in the area of both continuous time and discrete time dynamics and chaotic systems Discusses multidisciplinary applications with new fundamentals modeling analysis design realization and experimental results Includes circuits and systems based on new nonlinear elements Covers most of the linear and nonlinear fractional order theorems that will solve many scientific issues for researchers Closes the gap between theoretical approaches and real world applications Provides MATLAB and Simulink code for many applications in the book Interior Point Approach to Linear, Quadratic and Convex Programming D. den Hertog,2012-12-06 This book describes

the rapidly developing field of interior point methods IPMs An extensive analysis is given of path following methods for linear programming quadratic programming and convex programming These methods which form a subclass of interior point methods follow the central path which is an analytic curve defined by the problem Relatively simple and elegant proofs for polynomiality are given The theory is illustrated using several explicit examples Moreover an overview of other classes of IPMs is given It is shown that all these methods rely on the same notion as the path following methods all these methods use the central path implicitly or explicitly as a reference path to go to the optimum For specialists in IPMs as well as those seeking an introduction to IPMs The book is accessible to any mathematician with basic mathematical programming knowledge **Self-Organised Criticality** Gunnar Pruessner,2012-08-30 An overview of results and methods written for graduates and researchers in physics mathematics biology sociology finance medicine and engineering *Advances and Applications in Chaotic Systems* Sundarapandian Vaidyanathan,Christos Volos,2016-03-22 This book reports on the latest advances and applications of chaotic systems It consists of 25 contributed chapters by experts who are specialized in the various topics addressed in this book The chapters cover a broad range of topics of chaotic systems such as chaos hyperchaos jerk systems hyperjerk systems conservative and dissipative systems circulant chaotic systems multi scroll chaotic systems finance chaotic system highly chaotic systems chaos control chaos synchronization circuit realization and applications of chaos theory in secure communications mobile robot memristors cellular neural networks etc Special importance was given to chapters offering practical solutions modeling and novel control methods for the recent research problems in chaos theory This book will serve as a reference book for graduate students and researchers with a basic knowledge of chaos theory and control systems The resulting design procedures on the chaotic systems are emphasized using MATLAB software

Phase Portraits Of Control Dynamical Systems: Bestsellers in 2023 The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous engrossing novels captivating the hearts of readers worldwide. Lets delve into the realm of top-selling books, exploring the engaging narratives that have enthralled audiences this year. Phase Portraits Of Control Dynamical Systems : Colleen Hoovers "It Ends with Us" This heartfelt tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover masterfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can triumph. Phase Portraits Of Control Dynamical Systems : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This spellbinding historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids captivating storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Phase Portraits Of Control Dynamical Systems : Delia Owens "Where the Crawdads Sing" This evocative coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens weaves a tale of resilience, survival, and the transformative power of nature, captivating readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of captivating stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a exceptional and gripping novel that will keep you speculating until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

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