Delay Systems From Theory To Numerics And Applications

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CHRISTINE PETERSEN

Biological Delay Systems Springer
The beginning of the 21st century can be characterized as the" time-delay boom" leading to numerous important results. The purpose of this book is two-fold, to familiarize the non-expert reader with time-delay systems and to provide a systematic treatment of modern ideas and techniques for experts. This book is based on the course "Introduction to time-delay systems" for graduate students in Engineering and Applied Mathematics that the author taught in Tel Aviv University in 2011-2012 and 2012-2013 academic years. The sufficient background to follow most of the material are the undergraduate courses in mathematics and an introduction to control. The book leads the reader from some basic classical results on time-delay systems to recent developments on Lyapunov-based analysis and design with applications to the hot topics of sampled-data and network-based control. The objective is to provide useful tools that will allow the reader not only to

apply the existing methods, but also to develop new ones. It should be of interest for researchers working in the field, for graduate students in engineering and applied mathematics, and for practicing engineers. It may also be used as a textbook for a graduate course on time-delay systems.

Stability and Control of Time-delay Systems Springer

Control Strategy for Time-Delay Systems Part I: Concepts and Theories covers all the important features of real-world practical applications which will be valuable to practicing engineers and specialists, especially given that delays are present in 99% of industrial processes. The book presents the views of the editors on promising research directions and future industrial applications in this area. Although the fundamentals of time-delay systems are discussed, the book focuses on the advanced modeling and control of such systems and will provide the analysis and test (or simulation) results of nearly every technique described. For this purpose, highly complex models are introduced to ?describe the mentioned new applications, which are characterized by ?time-varying delays with intermittent and stochastic nature, several types of nonlinearities, and the presence ?of different time-scales. Researchers, practitioners, and PhD students will gain insights into the prevailing trends in design and operation of real-time control systems, reviewing the shortcomings and future developments concerning practical system issues, such as standardization, protection, and design. Presents an overview of the most recent trends for time-delay systems Covers the important features of the real-world practical applications that can be valuable to practicing engineers and specialists Provides analysis and simulations results of the techniques described in the book

Time-Delay Systems SIAM

Synchronization of chaotic systems, a patently nonlinear phenomenon, has emerged as a highly active interdisciplinary research topic at the interface of physics, biology, applied mathematics and engineering sciences. In this connection, time-delay systems described by delay differential equations have developed as particularly suitable tools for modeling specific dynamical systems. Indeed, time-delay is ubiquitous in many physical systems, for example due to finite switching speeds of amplifiers in electronic circuits, finite lengths of vehicles in traffic flows, finite signal propagation times in biological networks and circuits, and quite generally whenever memory effects are relevant. This monograph presents the basics of chaotic time-delay systems and their synchronization with an emphasis on the effects of time-delay feedback which give rise to new collective dynamics. Special attention is devoted to scalar chaotic/hyperchaotic time-delay systems, and some higher order models, occurring in different branches of science and technology as well as to the synchronization of their coupled versions. Last but not least, the presentation as a whole strives for a balance between the necessary mathematical description of the basics and the detailed presentation of real-world applications.

Stability and Stabilization of Time-Delay Systems Princeton University Press

Time-delay occurs in many dynamical systems such as biological systems, chemical systems, metallurgical

processing systems, nuclear reactor, long transmission lines in pneumatic, hydraulic systems and electrical networks. Especially, in recent years, time-delay which exists in networked control s- temshasbroughtmorecomplexprobleminto anewresearcharea.Frequently, itisasourceofthegenerationofoscillation,inst abilityandpoorperformance. Considerable e?ort has been applied to di?erent aspects of linear time-delay systems during recent years. Because the introduction of the delay factor renders the system analysis more complicated, in addition to the di?culties caused by the perturbation or uncertainties, in the control of time-delay s- tems, the problems of robust stability and robust stabilization are of great importance. This book presents some basic theories of stability and stabilization of systems with time-delay, which are related to the main results in this book. More attention will be paid on synthesis of systems with time-delay. That is, sliding mode control of systems with time-delay; networked control systems with time-delay; networked data fusion with random delay.

Applied Delay Differential Equations Springer

This book comprehensively presents a recently developed novel methodology for analysis and control of time-delay systems. Time-delays frequently occurs in engineering and science. Such time-delays can cause problems (e.g. instability) and limit the achievable performance of control systems. The concise and self-contained volume uses the Lambert W function to obtain solutions to time-delay systems represented by delay differential equations. Subsequently, the solutions are used to analyze essential system properties and to design controllers precisely and effectively.

Predictor Feedback for Delay Systems: Implementations and Approximations Springer Science & Business Media

This book introduces a new set of orthogonal hybrid functions (HF) which approximates time functions in a piecewise linear manner which is very suitable for practical applications. The book presents an analysis of different systems namely, time-invariant system, time-varying system, multi-delay systems---both homogeneous and non-homogeneous type- and the solutions are obtained in the form of discrete samples. The book also investigates system identification problems for many of the above systems. The book is spread over 15 chapters and contains 180 black and white figures, 18 colour figures, 85 tables and 56 illustrative examples. MATLAB codes for many such examples are included at the end of the book.

Analysis and Synthesis of Time Delay Systems Springer Science & Business Media

With neutral differential equations, any lack of smoothness in initial conditions is not damped and so they have proven to be difficult to solve. Until now, there has been little information to help with this problem. Oscillation Theory for Neutral Differential Equations with Delay fills a vacuum in qualitative theory of functional differential equations of neutral type. With much of the presented material previously unavailable outside Eastern Europe, this authoritative book provides a stimulus to research the oscillatory and asymptotic properties of these equations. It examines equations of first, second, and higher orders as well as the asymptotic behavior for tending toward infinity. These results

are then generalized for partial differential equations of neutral type. The book also describes the historical development of the field and discusses applications in mathematical models of processes and phenomena in physics, electrical control and engineering, physical chemistry, and mathematical biology. This book is an important tool not only for mathematicians, but also for specialists in many fields including physicists, engineers, and biologists. It may be used as a graduate-level textbook or as a reference book for a wide range of subjects, from radiophysics to electrical and control engineering to biological science.

Oscillation Theory for Neutral Differential Equations with Delay

Springer

Advanced Control Systems: Theory and Applications provides an overview of advanced research lines in control systems as well as in design, development and implementation methodologies for perspective control systems and their components in different areas of industrial and special applications. It consists of extended versions of the selected papers presented at the XXV International Conference on Automatic Control “Automatics 2018” (September 18-19, 2018, Lviv, Ukraine) which is the main Ukrainian Control Conference organized by Ukrainian Association on Automatic Control (National member organization of IFAC) and Lviv National University “Lvivska Politechnica”. More than 100 papers were presented at the conference with topics including: mathematical problems of control, optimization and game theory; control and identification under uncertainty; automated control of technical, technological and biotechnical objects; controlling the aerospace craft, marine vessels and other moving objects; intelligent control and information processing; mechatronics and robotics; information measuring technologies in automation; automation and IT training of personnel; the Internet of things and the latest technologies. The book is divided into two main parts, the first concerning theory (7 chapters) and the second concerning applications (7 chapters) of advanced control systems. The first part “Advances in Theoretical Research on Automatic Control” consists of theoretical research results which deal with descriptor control impulsive delay systems, motion control in condition of conflict, inverse dynamic models, invariant relations in optimal control, robust adaptive control, bio-inspired algorithms, optimization of fuzzy control systems, and extremal routing problem with constraints and complicated cost functions. The second part “Advances in Control Systems Applications” is based on the chapters which consider different aspects of practical implementation of advanced control systems, in particular, special cases in determining the spacecraft position and attitude using computer vision system, the spacecraft orientation by information from a system of stellar sensors, control synthesis of rotational and spatial spacecraft motion at approaching stage of docking, intelligent algorithms for the automation of complex biotechnical objects, an automatic control system for the slow pyrolysis of organic substances with variable composition, simulation complex of hierarchical systems based on the foresight and cognitive modelling, and advanced identification of impulse processes in cognitive maps. The chapters

have been structured to provide an easy-to-follow introduction to the topics that are addressed, including the most relevant references, so that anyone interested in this field can get started in the area. This book may be useful for researchers and students who are interesting in advanced control systems.

Introduction to Time-Delay Systems

Academic Press

One of the major contemporary challenges in both physical and social sciences is modeling, analyzing, and understanding the self-organization, evolution, behavior, and eventual decay of complex dynamical systems ranging from cell assemblies to the human brain to animal societies. The multi-faceted problems in this domain require a wide range of methods from various scienti?c disciplines. There is no question that the inclusion of time delays in complex system models considerably enriches the challenges presented by the problems. Although this inclusion often becomes inevitable as real-world applications demand more and more realistic m- els, the role of time delays in the context of complex systems so far has not attracted the interest it deserves. The present volume is an attempt toward ?lling this gap. There exist various useful tools for the study of complex time-delay systems. At the forefront is the mathematical theory of delay equations, a relatively mature ?eld in many aspects, which provides some powerful techniques for analytical inquiries, along with some other tools from statistical physics, graph theory, computer science, dynamical systems theory, probability theory, simulation and optimization software, and so on. Nevertheless, the use of these methods requires a certain synergy to address complex systems problems, especially in the presence of time delays.

Control Strategy for Time-Delay Systems

Springer Science & Business Media

This book presents the recently introduced and already widely referred semi-discretization method for the stability analysis of delayed dynamical systems. Delay differential equations often come up in different fields of engineering, like feedback control systems, machine tool vibrations, balancing/stabilization with reflex delay. The behavior of such systems is often counter-intuitive and closed form analytical formulas can rarely be given even for the linear stability conditions. If parametric excitation is coupled with the delay effect, then the governing equation is a delay differential equation with time periodic coefficients, and the stability properties are even more intriguing. The semi-discretization method is a simple but efficient method that is based on the discretization with respect to the delayed term and the periodic coefficients only. The method can effectively be used to construct stability diagrams in the space of system parameters.

PID Controllers for Time-Delay Systems

Academic Press

Time-delay occurs in many physical, industrial and engineering systems such as biological systems, chemical systems, metallurgical processing systems, nuclear reactors, hydraulic systems and electrical networks, to name a few. The reason for the occurrence could be attributed to inherent physical phenomena like mass transport flow or recycling. It could result from the finite capabilities of information processing and data transmission among various parts of the system. In addition, they could be by-products of computational delays or could be

intentionally introduced for some design consideration. Such delays could be constant or time varying, known or unknown, deterministic or stochastic depending on the system under consideration. In recent years, time-delay, which exists in networked control systems, has brought more complex problems into a new research area. Frequently, it is a source of the generation of oscillation, instability and poor performance. Therefore, the subject of Time-Delay Systems (TDS) has been investigated as functional differential equations over the past four decades. Because the presence of the delay factor renders the system analysis more complicated, the problems of stability and stabilization are of great importance. This book presents some basic theories of stability and stabilization of systems with time-delays. More attention is paid to the synthesis of systems with time-delay. That is, control of nonlinear systems with delay; networked control systems; positive delay systems; fuzzy systems; and reset control with random delay are all analysed within this book.

Advances in Time-Delay Systems

Birkhäuser

This book provides an introduction to the analysis and control of Linear Parameter-Varying Systems and Time-Delay Systems and their interactions. The purpose is to give the readers some fundamental theoretical background on these topics and to give more insights on the possible applications of these theories. This self-contained monograph is written in an accessible way for readers ranging from undergraduate/PhD students to engineers and researchers willing to know more about the fields of time-delay systems, parameter-varying systems, robust analysis, robust control, gain-scheduling techniques in the LPV fashion and LMI based approaches. The only prerequisites are basic knowledge in linear algebra, ordinary differential equations and (linear) dynamical systems. Most of the results are proved unless the proof is too complex or not necessary for a good understanding of the results. In the latter cases, suitable references are systematically provided. The first part pertains on the representation, analysis and control of LPV systems along with a reminder on robust analysis and control techniques. The second part is concerned with the representation and analysis of time-delay systems using various time-domain techniques. The third and last part is devoted to the representation, analysis, observation, filtering and control of LPV time-delay systems. The book also presents many important basic and advanced results on the manipulation of LMIs.

Delay-Doppler Communications

Springer

"Complex Systems: Fractionality, Time-delay and Synchronization" covers the most recent developments and advances in the theory and application of complex systems in these areas. Each chapter was written by scientists highly active in the field of complex systems. The book discusses a new treatise on fractional dynamics and control, as well as the new methods for differential delay systems and control. Lastly, a theoretical framework for the complexity and synchronization of complex system is presented. The book is intended for researchers in the field of nonlinear dynamics in mathematics, physics and engineering. It can also serve as a reference book for graduate students

in physics, applied mathematics and engineering. Dr. Albert C.J. Luo is a Professor at Southern Illinois University Edwardsville, USA. Dr. Jian-Qiao Sun is a Professor at the University of California, Merced, USA.

Robust Control of Time-delay Systems Springer

Basic predictor feedback for single-input systems -- Basic idea of adaptive control for single-input systems -- Single-input systems with full relative degree -- Single-input systems with arbitrary relative degree -- Exact predictor feedback for multi-input systems -- Full-state feedback of uncertain multi-input systems -- Output feedback of uncertain multi-input systems -- Output feedback of systems with uncertain delays, parameters and ODE state -- Predictor feedback for uncertainty-free systems -- Predictor feedback of uncertain single-input systems -- Predictor feedback of uncertain multi-input systems.

Delay Compensation for Nonlinear, Adaptive, and PDE Systems Springer Science & Business Media

This monograph bridges the gap between the nonlinear predictor as a concept and as a practical tool, presenting a complete theory of the application of predictor feedback to time-invariant, uncertain systems with constant input delays and/or measurement delays. It supplies several methods for generating the necessary real-time solutions to the systems' nonlinear differential equations, which the authors refer to as approximate predictors. Predictor feedback for linear time-invariant (LTI) systems is presented in Part I to provide a solid foundation on the necessary concepts, as LTI systems pose fewer technical difficulties than nonlinear systems. Part II extends all of the concepts to nonlinear time-invariant systems. Finally, Part III explores extensions of predictor feedback to systems described by integral delay equations and to discrete-time systems. The book's core is the design of control and observer algorithms with which global stabilization, guaranteed in the previous literature with idealized (but non-implementable) predictors, is preserved with approximate predictors developed in the book. An applications-driven engineer will find a large number of explicit formulae, which are given throughout the book to assist in the application of the theory to a variety of control problems. A mathematician will find sophisticated new proof techniques, which are developed for the purpose of providing global stability guarantees for the nonlinear infinite-dimensional delay system under feedback laws employing practically implementable approximate predictors. Researchers working on global stabilization problems for time-delay systems will find this monograph to be a helpful summary of the state of the art, while graduate students in the broad field of systems and control will advance their skills in nonlinear control design and the analysis of nonlinear delay systems.

Applications of Time Delay Systems Springer Science & Business Media

Time delays are important components of many systems in, for instance, engineering, physics, economics, and the life sciences, because the transfer of material, energy, and information is usually not instantaneous. Time delays may appear as computation and communication lags, they model transport phenomena and heredity, and they arise as feedback delays in control loops. This monograph addresses the problem of

stability analysis, stabilization, and robust fixed-order control of dynamical systems subject to delays, including both retarded- and neutral-type systems. Within the eigenvalue-based framework, an overall solution is given to the stability analysis, stabilization, and robust control design problem, using both analytical methods and numerical algorithms and applicable to a broad class of linear time-delay systems.? In this revised edition, the authors make the leap from stabilization to the design of robust and optimal controllers and from retarded-type to neutral-type delay systems, thus enlarging the scope of the book within control; include new, state-of-the-art material on numerical methods and algorithms to broaden the book?s focus and to reach additional research communities, in particular numerical linear algebra and numerical optimization; and increase the number and range of applications to better illustrate the effectiveness and generality of their approach.?

Control Strategy for Time-Delay Systems SIAM

This book presents the authors' recent work on the numerical methods for the stability analysis of linear autonomous and periodic delay differential equations, which consist in applying pseudospectral techniques to discretize either the solution operator or the infinitesimal generator and in using the eigenvalues of the resulting matrices to approximate the exact spectra. The purpose of the book is to provide a complete and self-contained treatment, which includes the basic underlying mathematics and numerics, examples from population dynamics and engineering applications, and Matlab programs implementing the proposed numerical methods. A number of proofs is given to furnish a solid foundation, but the emphasis is on the (unifying) idea of the pseudospectral technique for the stability analysis of DDEs. It is aimed at advanced students and researchers in applied mathematics, in dynamical systems and in various fields of science and engineering, concerned with delay systems. A relevant feature of the book is that it also provides the Matlab codes to encourage the readers to experience the practical aspects. They could use the codes to test the theory and to analyze the performances of the methods on the given examples. Moreover, they could easily modify them to tackle the numerical stability analysis of their own delay models.

Time Delay Systems Springer Science & Business Media

This book provides an update of the latest research in control of time delay systems and applications by world leading experts. It will appeal to engineers, researchers and students in Control.

Dynamics of Nonlinear Time-Delay Systems Springer Science & Business Media

Orthogonal Frequency Division Multiplexing (OFDM) has been the waveform of choice for most wireless communications systems in the past 25 years. This book addresses the "what comes next? question by presenting the recently proposed waveform known as Orthogonal Time-Frequency-Space (OTFS), which offers a better alternative for high-mobility environments. The OTFS waveform is based on the idea that the mobile wireless channels can be effectively modelled in the delay-Doppler domain. This domain provides a sparse representation closely resembling the physical geometry of the wireless channel.

The key physical parameters such as relative velocity and distance of the reflectors with respect to the receiver can be considered roughly invariant in the duration of a frame up to a few milliseconds. This enables the information symbols encoded in the delay-Doppler domain to experience a flat fading channel even when they are affected by multiple Doppler shifts present in high-mobility environments. Delay-Doppler Communications: Principles and Applications covers the fundamental concepts and the underlying principles of delay-Doppler communications. Readers familiar with OFDM will be able to quickly understand the key differences in delay-Doppler domain waveforms that can overcome some of the challenges of high-mobility communications. For the broader readership with a basic knowledge of wireless communications principles, the book provides sufficient background to be self-contained. The book provides a general overview of future research directions and discusses a range of applications of delay-Doppler domain signal processing. - This is the first book on delay-Doppler communications - It is written by three of the leading authorities in the field - It includes a wide range of applications With this book, the reader will be able to: - Recognize the challenges of high-mobility channels affected by both multipath and multiple Doppler shifts in physical layer waveform design and performance - Understand the limitations of current multicarrier techniques such as OFDM in high-mobility channels - Recognize the mathematical and physical relations between the different domains for representing channels and waveforms: time-frequency, time-delay, delay-Doppler - Understand the operation of the key blocks of a delay-Doppler modulator and demodulator both analytically and by hands-on MATLAB examples - Master the special features and advantages of OTFS with regard to detection, channel estimation, MIMO, and multiuser MIMO - Realize the importance of delay-Doppler communications for current and future applications, e.g., 6G and beyond

Semi-Discretization for Time-Delay Systems Springer Science & Business Media

The authors have developed a methodology for control of nonlinear systems in the presence of long delays, with large and rapid variation in the actuation or sensing path, or in the presence of long delays affecting the internal state of a system. In addition to control synthesis, they introduce tools to quantify the performance and the robustness properties of the designs provided in the book. The book is based on the concept of predictor feedback and infinite-dimensional backstepping transformation for linear systems and the authors guide the reader from the basic ideas of the concept?with constant delays only on the input?all the way through to nonlinear systems with state-dependent delays on the input as well as on system states. Readers will find the book useful because the authors provide elegant and systematic treatments of long-standing problems in delay systems, such as systems with state-dependent delays that arise in many applications. In addition, the authors give all control designs by explicit formulae, making the book especially useful for engineers who have faced delay-related challenges and are concerned with actual implementations and they accompany all control designs with

Lyapunov-based analysis for establishing stability and performance guarantees.

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