Introduction To Time Delay Systems Analysis And Control Systems Control Foundations Applications

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.

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- temshasbroughtmorecomplexproblemintoanewresearcharea.Frequently, itisasourceofthegenerationofoscillation,instabilityandpoorperformance. 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.

This volume is the first of the new series Advances in Dynamics and Delays. It offers the latest advances in the research of analyzing and controlling dynamical systems with delays, which arise in many real-world problems. The contributions in this series are a collection across various disciplines, encompassing engineering, physics, biology, and economics, and some are extensions of those presented at the IFAC (International Federation of Automatic Control) conferences since 2011. The series is categorized in five parts covering the main themes of the contributions: · Stability Analysis and Control Design · Networks and Graphs · Time Delay and Sampled-Data Systems · Computational and Software Tools · Applications This volume will become a good reference point for researchers and PhD students in the field of delay systems, and for those willing to learn more about the field, and it will also be a resource for control engineers, who will find innovative control methodologies for relevant applications, from both theory and numerical analysis perspectives.

This book provides a systematic approach to the design of predictor based controllers for (time-varying) linear systems with either (time-varying) input or state delays. Differently from those traditional predictor based controllers, which are infinite-dimensional static feedback laws and may cause difficulties in their practical implementation, this book develops a truncated predictor feedback (TPF) which involves only finite dimensional static state feedback. Features and topics: A novel approach referred to as truncated predictor feedback for the stabilization of (time-varying) time-delay systems in both the continuous-time setting and the discrete-time setting is built systematically Semi-global and global stabilization problems of linear time-delay systems subject to either magnitude saturation or energy constraints are solved in a systematic manner Both stabilization of a single system and consensus of a group of systems (multi-agent systems) are treated in a unified manner by applying the truncated predictor feedback and predictor feedback The properties of the solutions to a class of parametric (differential and difference) Lyapunov matrix equations are presented in detail Detailed numerical examples and applications to the spacecraft rendezvous and formation flying problems are provided to demonstrate the usefulness of the presented theoretical results This book can be a useful resource for the researchers, engineers, and graduate students in the fields of control, applied mathematics, mechanical engineering, electrical engineering, and aerospace engineering.

Applications of Time Delay Systems

A Geometric Approach

Part II: Engineering Applications

Analysis and Control Using the Lambert W Function

Stability and Control of Time-delay Systems

Dynamic Systems with Time Delays: Stability and Control

This book is about time-domain modelling, stability, stabilization, control design and filtering for JTDS. It gives readers a thorough understanding of the basic mathematical analysis and fundamentals, offers a straightforward treatment of the different topics and provides broad coverage of the recent methodologies.

This book presents up-to-date research developments and novel methodologies to solve various stability and control problems of dynamic systems with time delays. First, it provides the new introduction of integral and summation inequalities for stability analysis of nominal time-delay systems in continuous and discrete time domain, and presents corresponding stability conditions for the nominal system and an applicable nonlinear system. Next, it investigates several control problems for dynamic systems with delays including H(infinity) control problem Event-triggered control problems; Dynamic output feedback control problems; Reliable sampled-data control problems. Finally, some application topics covering filtering, state estimation, and synchronization are considered. The book will be a valuable resource and guide for graduate students, scientists, and engineers in the system sciences and control communities.

This authored monograph presents a study on fundamental limits and robustness of stability and stabilization of time-delay systems, with an emphasis on time-varying delay, robust stabilization, and newly emerged areas such as networked control and multi-agent systems. The authors systematically develop an operator-theoretic approach that departs from both the traditional algebraic approach and the currently pervasive LMI solution methods. This approach is built on the classical small-gain theorem, which enables the author to draw upon powerful tools and techniques from robust control theory. The book contains motivating examples and presents mathematical key facts that are required in the subsequent sections. The target audience primarily comprises researchers and professionals in the field of control theory, but the book may also be beneficial for graduate students alike.

Although the last decade has witnessed significant advances in control theory for finite and infinite dimensional systems, the stability and control of time-delay systems have not been fully investigated. Many problems exist in this field that are still unresolved, and there is a tendency for the numerical methods available either to be too general or too specific to be applied accurately across a range of problems. This monograph brings together the latest trends and new results in this field, with the aim of presenting methods covering a large range of techniques. Particular emphasis is placed on methods that can be directly applied to specific problems. The resulting book is one that will be of value to both researchers and practitioners.

Time Delay ODE/PDE Models

Delay Differential Equations

Biological Delay Systems

Lyapunov Functionals and Matrices

Truncated Predictor Feedback for Time-Delay Systems

Delay-Adaptive Linear Control

Time delays are present in many physical processes due to the period of time it takes for the events to occur. Delays are particularly more pronounced in networks of interconnected systems, such as supply chains and systems controlled over c- munication networks. In these control problems, taking the delays into account is particularly important for performance evaluation and control system's design. It has been shown, indeed, that delays in a controlled system (for instance, a c- munication delay for data acquisition) may have an "ambiguous" nature: they may stabilize the system, or, in the contrary,they may lead to deteriorationof the clos- loop performance or even instability, depending on the delay value and the system parameters. It is a fact that delays have stabilizing effects, but this is clearly con i- ing for human intuition. Therefore,speci c analysis techniquesand design methods are to be developed to satisfactorily take into account the presence of delays at the design stage of the control system. The research on time delay systems stretches back to 1960s and it has been very active during the last twenty years. During this period, the results have been presented at the main control conferences(CDC, ACC, IFAC), in specialized wo- shops (IFAC TDS series), and published in the leading journals of control engine- ing, systems and control theory, applied and numerical mathematics.

This book offers a comprehensive review of the modern theory of control systems described by functional-differential equations. The emphasis of the text is on methods and results that are applicable to analysis and synthesis of industrial control systems with time delays. Initial chapters contain examples of systems with delays and a presentation of typical control problems. Chapters also present basic results of the mathematical theory of functional-differential and discrete equations and cover identification of time-delay systems, stability theory, PID and Smith controllers, as well as the determination of stability regions, controller settings, and more. A review of controlability and observability results is presented, and optimal control is discussed in detail.

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 analyzed within this book--

Filling a gap in the literature, this book is a presentation of recent results in the field of PID controllers, including their design, analysis, and synthesis. Emphasis is placed on the efficient computation of the entire set of PID controllers achieving stability and various performance specifications, which is important for the development of future software design packages, as well as further capabilities such as adaptive PID design and online implementation. The results presented here are timely given the resurgence of interest in PID controllers and will find widespread application, specifically in the development of computationally efficient tools for PID controller design and analysis. Serving as a catalyst to bridge the theory--practice gap in the control field as well as the classical--modern gap, this monograph is an excellent resource for control, electrical, chemical, and mechanical engineers, as well as researchers in the field of PID controllers.

Analysis and Control

Finite-Time Stability: An Input-Output Approach

Time-Delay Systems

A Time-Delay Approach

Linear Stability Theory

Analysis, Observation, Filtering & Control

This brief focuses on the structural properties of nonlinear time-delay systems. It provides a link between coverage of fundamental theoretical properties and advanced control algorithms, as well as suggesting a path for the generalization of the differential geometric approach to time-delay systems . The brief begins with an introduction to a class of single-input nonlinear time-delay systems. It then focuses on geometric methods treating them and offers a geometric framework for integrability. The book has chapters dedicated to the accessibility and observability of nonlinear time-delay systems, allowing readers to understand the systems in a well-ordered, structured way. Finally, the brief concludes with applications of integrability and the control of single-input time-delay systems. This brief employs exercises and examples to familiarize readers with the time-delay context. It is of interest to researchers, engineers and postgraduate students who work in the area of nonlinear control systems.

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 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.÷

Delay Differential Equations emphasizes the global analysis of full nonlinear equations or systems. The book treats both autonomous and nonautonomous systems with various delays. Key topics addressed are the possible delay influence on the dynamics of the system, such as stability switching as time delay increases, the long time coexistence of populations, and the oscillatory aspects of the dynamics. The book also includes coverage of the interplay of spatial diffusion and time delays in some diffusive delay population models. The treatment presented in this monograph will be of great value in the study of various classes of DDEs and their multidisciplinary applications.

Analysis and Synthesis of Time Delay Systems

Topics in Time Delay Systems

Stability of Time-Delay Systems

Nonlinear Time-Delay Systems

Applications in Biomedical Science and Engineering

An Eigenvalue-Based Approach, Second Edition

More and more digital devices are being used for informa tion processing and control purposes in a variety of systems applications, including industrial processes, power networks, biological systems and communication networks. This trend has been helped by the advent of microprocessors and the consequent availability of cheap distributed computing power. For those applications, where digital devices are used, it is reasonable to model the system in discrete-time. In addition there are other application areas, e.g. econometric systems, business systems, certain command and control systems, environmental systems, where the underlying models are in discrete-time and here discrete-time approaches to analysis and control are the most appropriate. In order to deal with these two situations, there has been a lot of interest in developing techLiques which allow us to do analysis, design and control of discrete-time systems. This book provides a comprehensive treatment of discrete time dynamical systems. It covers the topics of modelling, optimization techniques and control design. The book is designed to serve as a text for teaching at the first year graduate level. The material included is organized into eight chapters.

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.

The book focuses on delay systems and their applications. We brought together well-known experts in the field to present a wide panorama of interdisciplinary methods in handling stability, control and related numerical issues. By reading the book, the readers will get a up-to-date picture of this active area of research as well as representative methods used in this field. This book can be used as a reference for both experts and novices interested in the research of time-delay, nonlinear systems, as well as analysis of time-delay systems.

The presence of considerable time delays in many industrial processes is well recognized and achievable performances of conventional unity feedback control systems are degraded if a process has a relatively large time delay compared to its time constants. In this case, dead time compensation is necessary in order to enhance the performances. The most popular scheme for such compensation is the Smith Predictor, but it is unsuitable for unstable or lightly damped processes because the compensated closed-loop system always contains the process poles themselves. An alternative scheme for delay elimination from the closed-loop is the finite spectrum assignment (FSA) strategy and it can arbitrarily assign the closed-loop spectrum. One may note that the Smith Predictor Control can be found in delay systems control books and many process control books, but the FSA control is rarely included in these books. It is therefore timely and desirable to fill this gap by writing a book which gives a comprehensive treatment of the FSA approach. This is useful and worthwhile since the FSA provides not only an alternative way but also certain advantages over the Smith-Predictor. The book presents the state-of-the-art of the finite spectrum assignment for time-delay systems in frequency domain. It mainly contains those works carried out recently by the authors in this field. Most of them have been published and others are awaiting publication. They are assembled together and reorganized in such a way that the presentation is logical, smooth and systematic.

Introduction to Time-Delay Systems

Time Delay Systems

Stability Analysis and Robust Control of Time-Delay Systems

Limits of Stability and Stabilization of Time-Delay Systems

Methodologies for Control of Jump Time-Delay Systems

Networked Control Under Communication Constraints

In many practical applications we deal with a wide class of dynamical systems that are comprised of a family of continuous-time or discrete-time subsystems and a rule orchestrating the switching between the subsystems. This class of systems is frequently called switched system. Switched linear systems provide a framework that bridges the linear systems and the complex and/or uncertain systems. The mo- vation for investigating this class of systems is twofold: ?rst, it has an inherent multi-modal behavior in the sense that several dynamical subsystems are required to describe their behavior, which might depend on various environmental factors. Second, the methods of intelligent control systems are based on the idea of swit- ing between different controllers. Looked at in this light, switched systems provide an integral framework to deal with complex system behaviors such as chaos and multiple limit cycles and gain more insights into powerful tools such as intelligent control, adaptive control, and robust control. Switched systems have been inves- gated for a long time in the control and systems literature and have increasingly attracted more attention for the past three decades. The number of journal articles, books, and conference papers have grown exponentially and a number of fundam- tal concepts and powerful tools have been developed. It has been pointed out that switched systems have been studied from various viewpoints.

"Stability Analysis and Robust Control of Time-Delay Systems" focuses on essential aspects of this field, including the stability analysis, stabilization, control design, and filtering of various time-delay systems. Primarily based on the most recent research, this monograph presents all the above areas using a free-weighting matrix approach first developed by the authors. The effectiveness of this method and its advantages over other existing ones are proven theoretically and illustrated by means of various examples. The book will give readers an overview of the latest advances in this active research area and equip them with a pioneering method for studying time-delay systems. It will be of significant interest to researchers and practitioners engaged in automatic control engineering. Prof. Min Wu, senior member of the IEEE, works at the Central South University, China.

0. 1 Introduction Although the general optimal solution of the ?ltering problem for nonlinear state and observation equations confused with white Gaussian noises is given by the Kushner equation for the conditional density of an unobserved state with respect to obser- tions (see [48] or [41], Theorem 6. 5, formula (6. 79) or [70], Subsection 5. 10. 5, formula (5. 10. 23)), there are a very few known examples of nonlinear systems where the Ku- ner equation can be reduced to a ?nite-dimensional closed system of ?ltering eq- tions for a certain number of lower conditional moments. The most famous result, the Kalman-Bucy ?lter [42], is related to the case of linear state and observation equations, where only two moments, the estimate itself and its variance, form a closed system of ?ltering equations. However, the optimal nonlinear ?nite-dimensional ?lter can be - tained in some other cases, if, for example, the state vector can take only a ?nite number of admissible states [91] or if the observation equation is linear and the drift term in the 2 2 state equation satis?es the Riccati equation df /dx + f = x (see [15]). The complete classi?cation of the " general situation " cases (this means that there are no special - sumptions on the structure of state and observation equations and the initial conditions), where the optimal nonlinear ?nite-dimensional ?lter exists, is given in [95].

This book is a self-contained presentation of the background and progress of the study of time-delay systems, a subject with broad applications to a number of areas.

With Applications in Population Dynamics
Delay Systems
Linear Parameter-Varying and Time-Delay Systems
Time-delay Systems
Discrete Systems
Analysis, Control and Optimization

An overall solution to the (robust) stability analysis and stabilisation problem of linear time-delay systems.

Since delays are present in 99% of industrial processes, Control Strategy for Time-delay Systems covers all the important features of real-world practical applications which will be valuable to practicing engineers and specialists 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 modelling and control of such systems and will provide the analysis and test (or simulation) results of nearly every technique described in the book 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 the practical system issues such as standardization, protection and design.

"Uncertainty is inherent in control systems. Consider the following example: as an aircraft flies, it consumes fuel, which causes its mass to decrease. In order to maintain stability, the autopilot mechanism must adapt to this (a priori unknown) change in mass. Delays also pose a challenge in control systems. If you have tried to maintain a comfortable water temperature while showering in a building with outdated plumbing, you will understand the difficulties that arise when a control system has significant delays: the controller (you) is forced to make decisions based on "old" information. The intersection of these two problems (estimating unknown parameters when a system has delays) poses a significant mathematical challenge. Delay-Adaptive Linear Control presents new mathematical techniques to handle the intersection of the two distinct types of uncertainty described above: adaptive constraints, and uncertainties caused by delays. Traditionally, the problems of adaption and delays have been treated separately. This book considers the intersection of these two problems, developing new techniques for addressing different combinations of uncertainty-all within a single, unified framework. This work has applications in electrical and mechanical engineering (unmanned aerial vehicles, robotic manipulators), biomedical engineering (3D printing, neuromuscular electrical stimulation), and management and traffic science (supply chains, traffic flow), among others. Beyond its practical importance, this work is also of significant theoretical interest, as it addresses mathematical challenges involved in the analysis and design of these systems"--

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.

PID Controllers for Time-Delay Systems
Dynamics of Nonlinear Time-Delay Systems
Stability, Control and Application of Time-Delay Systems
From Theory to Numerics and Applications
Part I: Concepts and Theories
Switched Time-Delay Systems

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 d 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 construct stability diagrams in the space of system parameters.

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 techniqu 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 th 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. Th 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 a graduate course on time-delay systems.

This book presents a time-delay approach to the analysis and synthesis of networked control systems (NCSs) under communication constraints. Differently from other approaches, the time-delay approach to NCSs allows communication delays to be larger than the sampling intervals in scheduling protocols. The book starts from a comprehensive introduction to three main approaches to sampled-data and networked control. It then focuses on time-delay approach, and the modelling of the closed-loop systems in the form of time-delay system. It presents discontinuous functional constructions that are efficient for NCSs in the presence of communications delays. Further, it highlights time-delay approaches developed to model and analyze NCSs under communication constraints, with a particular focus on dynamic quantization, round-robin, try-once-dis stochastic protocols. The results are first presented for the continuous-time NCSs and then extended to discrete-time NCSs. Discussing recent developments in Lyapunov-based analysis of NCSs under communication constraints, the book is a valuable resource for researchers interest and networked control, and time-delay systems, as well as for graduate students in automatic control and systems theory.

Stability, Control and Application of Time-Delay Systems gives a systematic description of these systems. It includes adequate designs of integrated modeling and control and frequency characterizations. Common themes revolve around creating certain synergies of modeling, analysis, and applications of time delay systems that achieve robust stability while retaining desired performance quality. The book provides innovative insights into the state-of-the-art of time-delay systems in both theory and practical aspects. It has been edited with an emphasis on presenting c theoretical and practical methodological approaches and techniques. Unifies existing and emerging concepts concerning time delay dynamical systems Provides a series of the latest results in large-delay analysis and multi-agent and thermal systems with delays Gives in each chapter r simulation results in order to reflect the engineering practice

Semi-Discretization for Time-Delay Systems
Control Strategy for Time-Delay Systems
Controllability of Singularly Perturbed Linear Time Delay Systems
A Small-Gain Approach
Stability, Control, and Computation for Time-Delay Systems
An Eigenvalue-Based Approach

This volume collects contributions related to selected presentations from the 12th IFAC Workshop on Time Delay Systems, Ann Arbor, June 28-30, 2015. The included papers present novel techniques and new results of delayed dynamical systems. The topical spectrum covers control theory, numerical analysis, engineering and biological applications as well as experiments and case studies. The target audience primarily comprises research experts in the field of time delay systems, but the book may also be beneficial for graduate students alike.

Stability is one of the most studied issues in the theory of time-delay systems, however the corresponding chapters of published volumes on time-delay systems do not include a comprehensive study of a counterpart of classical Lyapunov theory for linear delay free systems. The principal goal of the book is to fill this gap, and to provide readers with a systematic and exhaustive treatment of the basic concepts of the Lyapunov-Krasovskii approach to the stability analysis of linear time-delay systems. Time-Delay Systems: Lyapunov Functionals and Matrices will be of great use and interest to researchers and graduate students in automatic control and applied mathematics as well as practicing engineers involved in control system design.

Systematically presents the input-output finite-time stability (IO-FTS) analysis of dynamical systems, covering issues of analysis, design and robustness The interest in finite-time control has continuously grown in the last fifteen years. This book systematically presents the input-output finite-time stability (IO-FTS) analysis of dynamical systems, with specific reference to linear time-varying systems and hybrid systems. It discusses analysis, design and robustness issues, and includes applications to real world engineering problems. While classical FTS has an important theoretical significance, IO-FTS is a more practical concept, which is more suitable for real engineering applications, the goal of the research on this topic in the coming years. Key features: Includes applications to real world engineering problems. Input-output finite-time stability (IO-FTS) is a practical concept, useful to study the behavior of a dynamical system within a finite interval of time. Computationally tractable conditions are provided that render the technique applicable to time-invariant as well as time varying and impulsive (i.e. switching) systems. The LMIs formulation allows mixing the IO-FTS approach with existing control techniques (e. g. H∞ control, optimal control, pole placement, etc.). This book is essential reading for university researchers as well as post-graduate engineers practicing in the field of robust process control in research centers and industries. Topics dealt with in the book could also be taught at the level of advanced control courses for graduate students in the department of electrical and computer engineering, mechanical engineering, aeronautics and astronautics, and applied mathematics.

The intent of this book is to present a methodology for the formulation and computer implementation of mathematical models based on time delay ordinary differential equations (DODEs) and partial differential equations (DPDEs) in biomedical science and engineering (BMSE). The book applies DODE/DPDE models to biological/physiological systems through a series of examples. The first chapter has four example DODE applications that illustrate various properties of delayed systems. This discussion is then extended in the second chapter to an introductory DPDE model with the model solution presented as spatiotemporal numerical and 2D and 3D graphical (plotted) output. Subsequent chapters pertain to a series of DPDEBMSE applications. The author facilitates the use of the models with reasonable time and effort on modest computers. The book is intended for medical researchers, medical clinicians, biophysicists, biochemists, biomedical engineers, chemical engineers, applied mathematicians, and applied numerical analysts. The book can also be used at the graduate level for courses in computer-based numerical analysis of delay differential equations. R routines are included throughout the text, and readers can access the R compiler (system) from the Internet to execute the downloaded R routines. • Introduces time delay ordinary and partial differential equations (DODE/DPDEs) and their numerical computer-based integration (solution) • Illustrates the computer implementation of DODE/DPDE models with coding (programming) in R, a quality, open-source scientific programming system readily available from the Internet • Applies DODE/DPDE models to biological/physiological systems through a series of examples • Provides the R routines for all of the illustrative applications through a download link • Facilitates the use of the models with reasonable time and effort on modest computers

Stability and Control
New Trends in Optimal Filtering and Control for Polynomial and Time-Delay Systems
Stability and Stabilization of Time-Delay Systems
Concepts, Design and Stability Analysis
Stability and Engineering Applications
Analysis and Synthesis of Dynamical Systems with Time-Delays

In studying the dynamics of populations, whether of animals, plants or cells, it is crucial to allow for delays such as those due to gestation, maturation or transport. This book deals with a fundamental question in the analysis of the effects of delays, namely whether they affect the stability of steady states.

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.

This monograph provides a comprehensive analysis of the control of singularly perturbed time delay systems. Expanding on the author’s previous work on controllability of linear systems with delays in the state and control variables, this volume’s comprehensive coverage makes it a valuable addition to the field. Each chapter is self-contained, allowing readers to study them independently or in succession. After a brief introduction, the book systematically examines properties of different classes of singularly perturbed time delay systems, including linear time-dependent systems with multiple point-wise and distributed state delays. The author then considers more general singularly perturbed systems with state and control delays. Euclidean space controllability for all of these systems is also discussed, using numerous examples from real-life models throughout the text to illustrate the results presented. More technically complicated proofs are presented in separate subsections. The final chapter includes a section dedicated to non-linear time delay systems. This book is ideal for researchers, engineers, and graduate students in systems science and control theory. Other applied mathematicians and researchers working in biology and medicine will also find this volume to be a valuable resource.

Recently, there have been significant developments in robust control of time-delay systems. This volume presents a systematic treatment of robust control for such systems in the frequency domain. The emphasis is on systems with a single input or output delay, although the delay-free part of the plant can be multi-input-multi-output, in which case the delays in different channels should be the same. The author covers the whole range of H-infinity control of time-delay systems: from controller parameterization implementation; from the Nehari problem to the four-block problem; from theoretical developments to practical issues. The major tools used are similarity transformation, the chain-scattering approach and J-spectral factorization. Self-contained, "Robust Control of Time-delay Systems" will interest control theorists and mathematicians working with time-delay systems. Its methodical approach will be of value to graduates studying general robust control theory or its applications in time-delay systems.

Theory, Numerics, Applications, and Experiments
Finite-Spectrum Assignment for Time-Delay Systems
Robust Control of Time-delay Systems
Analysis, Algorithms and Control
Advances in Time-Delay Systems