Nonlinear And Adaptive Control Design

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Includes a solution manual for problems. Provides MATLAB code for examples and solutions. Deals with robust systems in both theory and practice.

In this book, modeling and control design of electric motors, namely step motors, brushless DC motors and induction motors, are considered. The book focuses on recent advances on feedback control designs for various types of electric motors, with a slight emphasis on stepper motors. For this purpose, the authors explore modeling of these devices to the extent needed to provide a high-performance controller, but at the same time one amenable to model-based nonlinear designs. The control designs focus primarily on recent robust adaptive nonlinear controllers to attain high performance. It is shown that the adaptive robust nonlinear controller on its own achieves reasonably good performance without requiring the exact knowledge of motor parameters. While carefully tuned classical controllers often achieve required performance in many applications, it is hoped that the advocated robust and adaptive designs will lead to standard universal controllers with minimal need for fine tuning of control parameters.

Robust and Adaptive Control shows the reader how to produce consistent and accurate controllers that operate in the presence of uncertainties and unforeseen events. Driven by aerospace applications the focus of the book is primarily on continuous-dynamical systems. The text is a three-part treatment, beginning with robust and optimal linear control methods and moving on to a self-contained presentation of the design and analysis of model reference adaptive control (MRAC) for nonlinear uncertain dynamical systems. Recent extensions and modifications to MRAC design are included, as are guidelines for combining robust optimal and MRAC controllers. Features of the text include: · case studies that demonstrate the benefits of robust and adaptive control for piloted, autonomous and experimental aerial platforms; · detailed background material for each chapter to motivate theoretical developments; · realistic examples and simulation data illustrating key features of the methods described; and · problem solutions for instructors and MATLAB® code provided electronically. The theoretical content and practical applications reported address real-life aerospace problems, being based on numerous transitions of control-theoretic results into operational systems and airborne vehicles that are drawn from the authors’ extensive professional experience with The Boeing Company. The systems covered are challenging, often open-loop unstable, with uncertainties in their dynamics, and thus requiring both persistently reliable control and the ability to track commands either from a pilot or a guidance computer. Readers are assumed to have a basic understanding of root locus, Bode diagrams, and Nyquist plots, as well as linear algebra, ordinary differential equations, and the use of state-space methods in analysis and modeling of dynamical systems. Robust and Adaptive Control is intended to methodically teach senior undergraduate and graduate students how to construct stable and predictable control algorithms for realistic industrial applications. Practicing engineers and academic researchers will also find the book of great instructional value.

This graduate-level text offers a thorough understanding of the global stability properties essential to designing adaptive systems. Its self-contained, unified presentation includes detailed case studies and numerous problems. 1989 edition.

A systematic and unified presentation of the fundamentals of adaptive control theory in both continuous time and discrete time Today, adaptive control theory has grown to be a rigorous and mature discipline. As the advantages of adaptive systems for developing advanced
applications grow apparent, adaptive control is becoming more popular in many fields of engineering and science. Using a simple, balanced, and harmonious style, this book provides a convenient introduction to the subject and improves one’s understanding of adaptive control theory. Adaptive Control Design and Analysis features: Introduction to systems and control Stability, operator norms, and signal convergence Adaptive parameter estimation State feedback adaptive control designs Parametrization of state observers for adaptive control Unified continuous and discrete-time adaptive control L1+a robustness theory for adaptive systems Direct and indirect adaptive control designs Benchmark comparison study of adaptive control designs Multivariate adaptive control designs Nonlinear adaptive control Adaptive compensation of actuator nonlinearities End-of-chapter discussion, problems, and advanced topics As either a textbook or reference, this self-contained tutorial of adaptive control design and analysis is ideal for practicing engineers, researchers, and graduate students alike.

The authors here provide a detailed treatment of the design of robust adaptive controllers for nonlinear systems with uncertainties. They employ a new tool based on the ideas of system immersion and manifold invariance. New algorithms are delivered for the construction of robust asymptotically-stabilizing and adaptive control laws for nonlinear systems. The methods proposed lead to modular schemes that are easier to tune than their counterparts obtained from Lyapunov redesign.

"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"--

Adaptive control is no longer just an important theoretical field of study, but is also providing solutions to real-world problems. Adaptive techniques will transform the world of control. The leading world practitioners of adaptive control have contributed to this handbook which is the most important work yet in this field. Not only are techniques described in theory, but detailed control algorithms are given, making this a practical cookbook of adaptive control for both control professionals and practising engineers. The book presents the most advanced techniques and algorithms of adaptive control. These include various robust techniques, performance enhancement techniques, techniques with less a-priori knowledge, nonlinear adaptive control techniques and intelligent adaptive techniques. Each technique described has been developed to provide a practical solution to a real-life problem. This volume will therefore not only advance the field of adaptive control as an area of study, but will also show how the potential of this technology can be realised and offer significant benefits. Practical cookbook of adaptive control Contains important research

In the last few years, adaptive control of nonlinear systems has emerged as an important area of research, with possible applications in areas
as diverse as robotic systems, electric motors, chemical processes, and automotive suspensions. Many of the existing results employ design methods and proof techniques borrowed from the adaptive linear control literature. As a consequence, they impose linear growth constraints on the nonlinearities in order to guarantee global stability. Such constraints bypass the true nonlinear problem and exclude many practically important systems. Furthermore, most existing results are based on the often unrealistic assumption of full-state feedback. In this thesis we construct fundamentally new systematic procedures for adaptive nonlinear control design, which yield global results without imposing any type of growth constraints on the nonlinearities and without requiring full-state feedback. This is achieved by identifying a set of basic tools from nonlinear and adaptive control and interlacing them in an intricate fashion to produce new design tools, which are used as building blocks in our design procedures. Each of these new procedures is applicable to nonlinear systems which can be expressed in a special canonical form. Since models of nonlinear systems are often derived from physical principles and given in specific coordinates, it may not always be obvious whether or not the nonlinear system at hand can be transformed into one of these canonical forms. Using differential geometric conditions, we derive coordinate-free characterizations for many of these forms, thereby identifying the classes of systems to which the corresponding design procedures are applicable.

This book, published in honor of Professor Laurent Praly on the occasion of his 65th birthday, explores the responses of some leading international authorities to new challenges in nonlinear and adaptive control. The mitigation of the effects of uncertainty and nonlinearity – ubiquitous features of real-world engineering and natural systems – on closed-loop stability and robustness being of crucial importance, the contributions report the latest research into overcoming these difficulties in: autonomous systems; reset control systems; multiple-input–multiple-output nonlinear systems; input delays; partial differential equations; population games; and data-driven control. Trends in Nonlinear and Adaptive Control presents research inspired by and related to Professor Praly’s lifetime of contributions to control theory and is a valuable addition to the literature of advanced control.

The robotic mechanism and its controller make a complete system. As the robotic mechanism is reconfigured, the control system has to be adapted accordingly. The need for the reconfiguration usually arises from the changing functional requirements. This book will focus on the adaptive control of robotic manipulators to address the changed conditions. The aim of the book is to summarise and introduce the state-of-the-art technologies in the field of adaptive control of robotic manipulators in order to improve the methodologies on the adaptive control of robotic manipulators. Advances made in the past decades are described in the book, including adaptive control theories and design, and application of adaptive control to robotic manipulators.

This book employs the powerful and popular adaptive backstepping control technology to design controllers for dynamic uncertain systems with non-smooth nonlinearities. Various cases including systems with time-varying parameters, multi-inputs and multi-outputs, backlash, dead-zone, hysteresis and saturation are considered in design and analysis. For multi-inputs and multi-outputs systems, both centralized and decentralized controls are addressed. This book not only presents recent research results including theoretical success and practical development such as the proof of system stability and the improvement of system tracking and transient performance, but also gives self-contained coverage of fundamentals on the backstepping approach illustrated with simple examples. Detail description of methodologies for the construction of adaptive laws, feedback control laws and associated Lyapunov functions is systematically provided in each case. Approaches used for the analysis of system stability and tracking and transient performances are elaborated. Two case studies are presented to show how the presented theories are applied.
Ch. 1. Generalized Hamiltonian systems / D. Cheng -- ch. 2. Continuous finite-time control / T. P. Leung and Y. Hong -- ch. 3. Local stabilization of nonlinear systems by dynamic output feedback / P. Chen and H. Qin -- ch. 4. Hybrid control for global stabilization of a class of systems / J. Zhao -- ch. 5. Robust and adaptive control of nonholonomic mechanical systems with applications to mobile robots / Y. M. Hu and W. Huo -- ch. 6. Introduction to chaos control and anti-control / G. Chen ...

The objective of the EU Nonlinear Control Network Workshop was to bring together scientists who are already active in nonlinear control and young researchers working in this field. This book presents selectively invited contributions from the workshop, some describing state-of-the-art subjects that already have a status of maturity while others propose promising future directions in nonlinear control. Amongst others, following topics of nonlinear and adaptive control are included: adaptive and robust control, applications in physical systems, distributed parameter systems, disturbance attenuation, dynamic feedback, optimal control, sliding mode control, and tracking and motion planning.

A highly accessible and unified approach to the design and analysis of intelligent control systems Adaptive Approximation Based Control is a tool every control designer should have in his or her control toolbox. Mixing approximation theory, parameter estimation, and feedback control, this book presents a unified approach designed to enable readers to apply adaptive approximation based control to existing systems, and, more importantly, to gain enough intuition and understanding to manipulate and combine it with other control tools for applications that have not been encountered before. The authors provide readers with a thought-provoking framework for rigorously considering such questions as: * What properties should the function approximator have? * Are certain families of approximators superior to others? * Can the stability and the convergence of the approximator parameters be guaranteed? * Can control systems be designed to be robust in the face of noise, disturbances, and unmodeled effects? * Can this approach handle significant changes in the dynamics due to such disruptions as system failure? * What types of nonlinear dynamic systems are amenable to this approach? * What are the limitations of adaptive approximation based control? Combining theoretical formulation and design techniques with extensive use of simulation examples, this book is a stimulating text for researchers and graduate students and a valuable resource for practicing engineers.

This volume surveys the major results and techniques of analysis in the field of adaptive control. Focusing on linear, continuous time, single-input, single-output systems, the authors offer a clear, conceptual presentation of adaptive methods, enabling a critical evaluation of these techniques and suggesting avenues of further development. 1989 edition.

Provides complete coverage of both the Lyapunov and Input-Output stability theories, in a readable, concise manner. * Supplies an introduction to the popular backstepping approach to nonlinear control design * Gives a thorough discussion of the concept of input-to-state stability * Includes a discussion of the fundamentals of feedback linearization and related results. * Details complete coverage of the fundamentals of dissipative systems' theory and its application in the so-called L2gain control problem, for the first time in an introductory level textbook. * Contains a thorough discussion of nonlinear observers, a very important problem, not commonly encountered in textbooks at this level. * An Instructor's Manual presenting detailed solutions to all the problems in the book is available from the Wiley editorial department.

Suitable for advanced undergraduates and graduate students, this overview introduces theoretical and practical aspects of adaptive control, with emphasis on deterministic and stochastic viewpoints. 1995 edition.
The area of adaptive systems, which encompasses recursive identification, adaptive control, filtering, and signal processing, has been one of the most active areas of the past decade. Since adaptive controllers are fundamentally nonlinear controllers which are applied to nominally linear, possibly stochastic and time-varying systems, their theoretical analysis is usually very difficult. Nevertheless, over the past decade much fundamental progress has been made on some key questions concerning their stability, convergence, performance, and robustness. Moreover, adaptive controllers have been successfully employed in numerous practical applications, and have even entered the marketplace.

The 1990 Grainger Lectures delivered at the University of Illinois, Urbana-Champaign, September 28 - October 1, 1990 were devoted to a critical reexamination of the foundations of adaptive control. In this volume the lectures are expanded by most recent developments and solutions for some long-standing open problems. Concepts and approaches presented are both novel and of fundamental importance for adaptive control research in the 1990s. The papers in Part I present unifications, reappraisals and new results on tunability, convergence and robustness of adaptive linear control, whereas the papers in Part II formulate new problems in adaptive control of nonlinear systems and solve them without any linear constraints imposed on the nonlinearities.

Nonlinear Control Design presents a self-contained introduction to nonlinear feedback control design for continuous time, finite-dimensional uncertain systems. It deals with nonlinear systems affected by uncertainties such as unknown constant parameters, time-varying disturbances, and uncertain nonlinearities. Both state feedback and output feedback are addressed. Differential geometric techniques are used to identify classes of nonlinear systems considered and to design feedback algorithms. Adaptive versions of these controls are developed in the presence of unknown parameters while robust versions are designed in the presence of time-varying disturbances. These control algorithms are applied to significant physical control problems from electric motor drives, robotics, aerospace, power systems and are illustrated through worked examples. The text is illustrated throughout with over 100 exercises, more than 75 worked examples and 12 physical examples.

This book introduces a comprehensive methodology for adaptive control design of parabolic partial differential equations with unknown functional parameters, including reaction-convection-diffusion systems ubiquitous in chemical, thermal, biomedical, aerospace, and energy systems. Andrey Smyshlyaev and Miroslav Krstic develop explicit feedback laws that do not require real-time solution of Riccati or other algebraic operator-valued equations. The book emphasizes stabilization by boundary control and using boundary sensing for unstable PDE systems with an infinite relative degree. The book also presents a rich collection of methods for system identification of PDEs, methods that employ Lyapunov, passivity, observer-based, swapping-based, gradient, and least-squares tools and parameterizations, among others. Including a wealth of stimulating ideas and providing the mathematical and control-systems background needed to follow the designs and proofs, the book will be of great use to students and researchers in mathematics, engineering, and physics. It also makes a valuable supplemental text for graduate courses on distributed parameter systems and adaptive control.

Shedding light on new opportunities in predictor feedback, this book significantly broadens the set of techniques available to a
mathematician or engineer working on delay systems. It is a collection of tools and techniques that make predictor feedback ideas applicable to nonlinear systems, systems modeled by PDEs, systems with highly uncertain or completely unknown input/output delays, and systems whose actuator or sensor dynamics are modeled by more general hyperbolic or parabolic PDEs, rather than by pure delay. Replete with examples, Delay Compensation for Nonlinear, Adaptive, and PDE Systems is an excellent reference guide for graduate students, researchers, and professionals in mathematics, systems control, as well as chemical, mechanical, electrical, computer, aerospace, and civil/structural engineering. Parts of the book may be used in graduate courses on general distributed parameter systems, linear delay systems, PDEs, nonlinear control, state estimator and observers, adaptive control, robust control, or linear time-varying systems.

This unified survey focuses on linear discrete-time systems and explores natural extensions to nonlinear systems. It emphasizes discrete-time systems, summarizing theoretical and practical aspects of a large class of adaptive algorithms. 1984 edition. Contains results not yet published in technical journals and conference proceedings.

Backstepping Control of Nonlinear Dynamical Systems addresses both the fundamentals of backstepping control and advances in the field. The latest techniques explored include ‘active backstepping control’, ‘adaptive backstepping control’, ‘fuzzy backstepping control’ and ‘adaptive fuzzy backstepping control’. The reference book provides numerous simulations using MATLAB and circuit design. These illustrate the main results of theory and applications of backstepping control of nonlinear control systems. Backstepping control encompasses varied aspects of mechanical engineering and has many different applications within the field. For example, the book covers aspects related to robot manipulators, aircraft flight control systems, power systems, mechanical systems, biological systems and chaotic systems. This multifaceted view of subject areas means that this useful reference resource will be ideal for a large cross section of the mechanical engineering community. Details the real-world applications of backstepping control Gives an up-to-date insight into the theory, uses and application of backstepping control Bridges the gaps for different fields of engineering, including mechanical engineering, aeronautical engineering, electrical engineering, communications engineering, robotics and biomedical instrumentation

Presented in a tutorial style, this comprehensive treatment unifies, simplifies, and explains most of the techniques for designing and analyzing adaptive control systems. Numerous examples clarify procedures and methods. 1995 edition.

This book presents innovative technologies and research results on adaptive control of dynamic systems with quantization, uncertainty and nonlinearity including theoretical success and practical development such as approaches for stability analysis, treatment of subsystem interactions, improvement of system tracking and transient performance.

In this work, the authors present a global perspective on the methods available for analysis and design of non-linear control systems and detail specific applications. They provide a tutorial exposition of the major non-linear systems analysis techniques followed by a discussion of available non-linear design methods.

The purpose of the book is to provide an exposition of recently developed adaptive and fault-tolerant control of underactuated
nonlinear systems. Underactuated systems are abundant in real life, ranging from landing vehicles to surface ships and underwater vehicles to spacecrafts. For the tracking and stabilization control of underactuated mechanical systems, many methodologies have been proposed. However, a number of important issues deserve further investigation. In response to these issues, four important problems are solved in this book, including control of underactuated nonlinear systems with input saturation, output-feedback control in the presence of parametric uncertainties, fault-tolerant control of underactuated ships with or without actuator redundancy, and adaptive control of multiple underactuated nonlinear systems, including formation control and flocking control of multiple underactuated systems.

This volume presents a theoretical framework and control methodology for a class of complex dynamical systems characterised by high state space dimension, multiple inputs and outputs, significant nonlinearity, parametric uncertainty, and unmodelled dynamics. A unique feature of the authors' approach is the combination of rigorous concepts and methods of nonlinear control (invariant and attracting submanifolds, Lyapunov functions, exact linearisation, passification) with approximate decomposition results based on singular perturbations and decentralisation. Some results published previously in the Russian literature and not well known in the West are brought to light. Basic concepts of modern nonlinear control and motivating examples are given. Audience: This book will be useful for researchers, engineers, university lecturers and postgraduate students specialising in the fields of applied mathematics and engineering, such as automatic control, robotics, and control of vibrations.

Designed to meet the needs of a wide audience without sacrificing mathematical depth and rigor, Adaptive Control Tutorial presents the design, analysis, and application of a wide variety of algorithms that can be used to manage dynamical systems with unknown parameters. Its tutorial-style presentation of the fundamental techniques and algorithms in adaptive control make it suitable as a textbook. Adaptive Control Tutorial is designed to serve the needs of three distinct groups of readers: engineers and students interested in learning how to design, simulate, and implement parameter estimators and adaptive control schemes without having to fully understand the analytical and technical proofs; graduate students who, in addition to attaining the aforementioned objectives, also want to understand the analysis of simple schemes and get an idea of the steps involved in more complex proofs; and advanced students and researchers who want to study and understand the details of long and technical proofs with an eye toward pursuing research in adaptive control or related topics. The authors achieve these multiple objectives by enriching the book with examples demonstrating the design procedures and basic analysis steps and by detailing their proofs in both an appendix and electronically available supplementary material; online examples are also available. A solution manual for instructors can be obtained by contacting SIAM or the authors. Preface; Acknowledgements; List of Acronyms; Chapter 1: Introduction; Chapter 2: Parametric Models; Chapter 3: Parameter Identification: Continuous Time; Chapter 4: Parameter Identification: Discrete Time; Chapter 5: Continuous-Time Model Reference Adaptive Control; Chapter 6: Continuous-Time Adaptive Pole Placement Control; Chapter 7: Adaptive Control for Discrete-Time Systems; Chapter 8: Adaptive Control of Nonlinear Systems; Appendix; Bibliography; Index

Model Free Adaptive Control: Theory and Applications summarizes theory and applications of model-free adaptive control (MFAC). MFAC is a novel adaptive control method for the unknown discrete-time nonlinear systems with time-varying parameters and time-varying structure,
and the design and analysis of MFAC merely depend on the measured input and output data of the controlled plant, which makes it more applicable for many practical plants. This book covers new concepts, including pseudo partial derivative, pseudo gradient, pseudo Jacobian matrix, and generalized Lipschitz conditions, etc.; dynamic linearization approaches for nonlinear systems, such as compact-form dynamic linearization, partial-form dynamic linearization, and full-form dynamic linearization; a series of control system design methods, including MFAC prototype, model-free adaptive predictive control, model-free adaptive iterative learning control, and the corresponding stability analysis and typical applications in practice. In addition, some other important issues related to MFAC are also discussed. They are the MFAC for complex connected systems, the modularized controller designs between MFAC and other control methods, the robustness of MFAC, and the symmetric similarity for adaptive control system design. The book is written for researchers who are interested in control theory and control engineering, senior undergraduates and graduated students in engineering and applied sciences, as well as professional engineers in process control.

Nonlinear and Adaptive Control Systems treats nonlinear control and adaptive control in a unified framework, presenting the major results at a moderate mathematical level, suitable to MSc students and engineers with undergraduate degrees.

An introduction to a new design for nonlinear control systems--backstepping--written by its own architects. This innovative book breaks new ground in nonlinear and adaptive control design for systems with uncertainties. Introducing the recursive backstepping methodology, it shows--for the first time--how uncertain systems with severe nonlinearities can be successfully controlled with this new powerful design tool. Communicative and accessible at a level not usually present in research texts, Nonlinear and Adaptive Control Design can be used as either a stand-alone or a supplemental text in courses on nonlinear or adaptive control, as well as in control research and applications. It eases the reader into the subject matter, assuming only standard undergraduate knowledge of control theory, and provides a pedagogical presentation of the material, most of which is completely new and not available in other textbooks. Written by the creators of backstepping, the book: * Introduces the basic design tools and demonstrates their effectiveness through worked examples * Provides detailed proofs and application examples (active suspension, jet engine, induction motor, and many others) * Develops adaptive backstepping, tuning functions, and modular designs with full state feedback * Generalizes the methodology to nonlinear systems with output feedback * Describes the advantages of the new adaptive nonlinear techniques over traditional methods * Offers a systematic methodology for performance improvement * Provides new designs for linear systems which can be used independently from the rest of the book * Is self-contained with an extensive summary of stability and passivity prerequisites * Includes sixty illustrations and tables with design algorithms Nonlinear and Adaptive Control Design is an absolute must for researchers and graduate students with an interest in nonlinear systems, adaptive control, stability and differential equations and for anyone who would like to find out about the new and exciting advances in these areas. 

Many of the non-smooth, non-linear phenomena covered in this well-balanced book are of vital importance in almost any field of engineering. Contributors from all over the world ensure that no one area’s slant on the subjects predominates.

Adaptive control has been one of the main problems studied in control theory. The subject is well understood, yet it has a very active research frontier. This book focuses on a specific subclass of adaptive control, namely, learning-based adaptive control. As systems evolve during time or are exposed to unstructured environments, it is expected that some of their characteristics may change. This book offers a new perspective about how to deal with these variations. By merging together Model-Free and Model-Based learning algorithms, the author demonstrates, using a number of mechatronic examples, how the learning process can be shortened and optimal control performance can be
reached and maintained. Includes a good number of Mechatronics Examples of the techniques. Compares and blends Model-free and Model-based learning algorithms. Covers fundamental concepts, state-of-the-art research, necessary tools for modeling, and control.