

# Robust Control of Uncertain Nonlinear Systems: A Nonlinear DOBC Approach

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## Abstract

This paper advocates disturbance observer based control (DOBC) for uncertain nonlinear systems. Within this framework, a nonlinear controller is designed based on the nominal model in the absence of disturbance and uncertainty where the main design specifications are to stabilize the system and achieve good tracking performance. Then a nonlinear disturbance observer is designed to not only estimate external disturbance but also system uncertainty/unmodelled dynamics. With described uncertainty, rigorous stability analysis of the closed-loop system under the composite controller is established in this paper. Finally, the robust control problems of a missile roll stabilization and a mass spring system are addressed to illustrate the distinct features of the nonlinear DOBC approach.

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## 1 Introduction

Robust control of uncertain nonlinear systems is deemed as one of the most crucial topics in modern control theory [1–3]. High-gain feedback domination technique is a major design tool utilized for robust suppression of uncertainties in nonlinear control theory [3]. However, it is generally claimed that most of existing robust control approaches are criticized as worst case based design, that is, the objective of the controller design is to achieve best performance in the presence of the worst uncertainties [4, 6]. Such a design philosophy involving in most of the existing robust control design methodologies would result in the following two major obstacles for its practical applications [6]. On the one hand, excessive control energy is usually required for the robust control to suppress the worst case uncertainties [5]. This would cause the waste of control energy as well as unreasonable selection of the actuator since powerful actuators are required to perform unnecessarily excessive control action demanded by the robust controllers. To this end, the conventional robust controller in practical engineering usually leads to input saturation problems [7, 8]. On the other hand, the robustness performance of these controllers are mostly obtained at a price of sacrificing the nominal control performance of the system because the control performance in the nominal case is usually not considered in the objective function of robust control [4, 6]. However, most practical systems are generally working around its nominal operation point and have a limited chance to operate far away from their nominal operation point. Taking a flight control system as an example, the flight envelop of the vehicle is generally around its nominal flight conditions. The extremely severe flight environment will but rarely appear in the whole flight process. The worst case based robust control design results in over conservative design. As such, a promising and practical robust controller should consider not only the robustness against the worst case of uncertainties but also the control performance around the nominal operation points.

Disturbance observer based control (DOBC) provides an alternative approach for robust control of nonlinear systems [9–11]. In the framework of nonlinear DOBC, the total uncertainties including external disturbances and internal

# Robust Control Of Nonlinear Uncertain Systems

**Franco Garofalo, Luigi Glielmo**



## **Robust Control Of Nonlinear Uncertain Systems:**

*Robust Control of Nonlinear Uncertain Systems* Zhihua Qu, 1998-04-29 This timely work presents the definitive treatment of stability analysis and robust control design for nonlinear uncertain systems While other books on the subject deal with robust control in linear systems this is the first book to tackle robust control design for such nonlinear entities as power systems robotics and more It combines examples proofs and applications clearly showing how to build high performance and better control into systems that are too complex to be modeled accurately A unique feature of this book is its Lyapunov based approach to control design which is the only universal approach for nonlinear systems The Lyapunov direct method is used here to develop all design procedures to correlate leading techniques in the field to the structural properties of uncertain systems and to compare robust and nonrobust types of controls such as adaptive control learning control and optimal control The subject is introduced with a self contained treatment of the nonlinear stability theory originally proposed by Lyapunov and LaSalle Emphasizing the basics the introductory chapters incorporate three types of solutions stability concepts and various theorems The main body of the text offers a comprehensive treatment for current design methods including state space robust control designs properties of various robust controllers input output control and discrete robust control designs In *Robust Control of Nonlinear Uncertain Systems* author Zhihua Qu presents the complete set of control design procedures for nonlinear uncertain systems including backward recursive design forward recursive design recursive interlacing design feedback linearization nonlinear optimal control and sub optimal control Also featured here is the breakthrough recursive interlacing design that facilitates robust control for uncertain systems with all cascaded feedback and feedforward dynamics Throughout Professor Qu presents the pros and cons of specific methods rationales for choosing particular design parameters and tips on questions of stability performance and systems structure For engineers and graduate students in mechanical electrical and aerospace engineering *Robust Control of Nonlinear Uncertain Systems* imparts the technical know how for effective design explores key theoretical issues in control and provides insight into future trends in the field

*Robust Control Designs for Nonlinear Uncertain Systems* Joseph Kaloust, 1995 The analysis and design of robust controllers are developed using Lyapunov's direct method Five different controllers are proposed designed and simulated for a certain class of nonlinear systems

**Development of Robust Control Based on Sliding Mode for Nonlinear Uncertain Systems** Xinming Yan, 2016 This work deals with the development of control laws for nonlinear uncertain systems based on sliding mode theory The standard sliding mode control approaches are state feedback ones in which the sliding variable and its time derivatives are required This first objective of this thesis is to propose high order sliding mode control laws with a reduced use of sliding variable time derivatives The contributions are made for the second and third order sliding mode control The second objective is to combine the proposed control laws with a gain adaptation mechanism The use of adaptive gain law allows to simplify the tuning process to reduce the convergence time and to improve the accuracy Finally

the applicability of the proposed approaches is shown on IRCCyN pneumatic benchmark Applications are also made on 3DOF flying system

Nonlinear Robust Control: Theory, Examples, and Applications Zhihua Qu, UNIVERSITY OF CENTRAL FLORIDA ORLANDO.,1993 Robust control design for stabilizing nonlinear uncertain systems is investigated Four issues are covered in the paper First existing and most recent research results in the area of nonlinear robust control design are summarized Second properties and features of nonlinear robust control are exposed through simple examples To show the potential that robust control theory can be applied to weapons systems a electrical mechanical system flexible joint robot is used as a prototype to proceed the design Finally the current research topics in theory and applications of nonlinear robust control are outlined

**Stabilization of Nonlinear Uncertain Systems** Miroslav Krstic, Hua Deng, 1998-05-21 This monograph presents the fundamentals of global stabilization and optimal control of nonlinear systems with uncertain models It offers a unified view of deterministic disturbance attenuation stochastic control and adaptive control for nonlinear systems The book addresses researchers in the areas of robust and adaptive nonlinear control nonlinear H infinity stochastic control and other related areas of control and dynamical systems theory

*Robust Backstepping Control of Nonlinear Uncertain Systems* Russell Edward Mills, 2001

Analysis and Decision Making in Uncertain Systems Zdzislaw Bubnicki, 2004-01-09 A unified and systematic description of analysis and decision problems within a wide class of uncertain systems described by traditional mathematical methods and by relational knowledge representations Prof Bubnicki takes a unique approach to stability and stabilization of uncertain systems

**Set-Theoretic Methods in Control** Franco Blanchini, Stefano Miani, 2015-07-02 The second edition of this monograph describes the set theoretic approach for the control and analysis of dynamic systems both from a theoretical and practical standpoint This approach is linked to fundamental control problems such as Lyapunov stability analysis and stabilization optimal control control under constraints persistent disturbance rejection and uncertain systems analysis and synthesis Completely self contained this book provides a solid foundation of mathematical techniques and applications extensive references to the relevant literature and numerous avenues for further theoretical study All the material from the first edition has been updated to reflect the most recent developments in the field and a new chapter on switching systems has been added Each chapter contains examples case studies and exercises to allow for a better understanding of theoretical concepts by practical application The mathematical language is kept to the minimum level necessary for the adequate formulation and statement of the main concepts yet allowing for a detailed exposition of the numerical algorithms for the solution of the proposed problems Set Theoretic Methods in Control will appeal to both researchers and practitioners in control engineering and applied mathematics It is also well suited as a textbook for graduate students in these areas Praise for the First Edition This is an excellent book full of new ideas and collecting a lot of diverse material related to set theoretic methods It can be recommended to a wide control community audience B T Polyak Mathematical Reviews This book is an outstanding monograph of a recent research trend in control It

reflects the vast experience of the authors as well as their noticeable contributions to the development of this field. It is highly recommended to PhD students and researchers working in control engineering or applied mathematics. The material can also be used for graduate courses in these areas.

Octavian Pastravanu Zentralblatt MATH **Contemporary Theory and Pragmatic Approaches in Fuzzy Computing Utilization** Chen, Toly, 2012-07-31 This book presents the most innovative systematic and practical facets of fuzzy computing technologies to students, scholars, and academicians, as well as practitioners, engineers, and professionals.

**Robust Control of Nonlinear Time-varying Mismatched Uncertain Systems** Wei Hua Wang, 1998 **Modern Optimal Control** E. O. Roxin, 1989-07-28 Scientific and Technical Aerospace Reports, 1993 *European Control Conference 1995*, 1995-09-05 Proceedings of the European Control Conference 1995 Rome Italy 5-8 September 1995 Robust Control Jürgen Ackermann, 2012-12-06 Many plants have large variations in operating conditions. To ensure smooth running, it is essential to find a simple fixed gain controller that guarantees rapidly decaying and well-damped transients for all admissible operating conditions. Robust Control presents design tools developed by the authors for the solution of this design problem. Examples of simple and complex cases, such as a crane, a flight control problem, and the automatic and active four-wheel steering of a car, illustrate the use of these tools. This book is intended for anyone who has taken an undergraduate course in feedback control systems and who seeks an advanced treatment of robust control with applications. Drawing on the resources and authoritative research of a leading aerospace institute, it will mainly be of interest to mechanical and electrical engineers in universities, institutes, and industrial research centres.

*Robust Control Via Variable Structure and Lyapunov Techniques* Franco Garofalo, Luigi Glielmo, 1996 A large part of today's fervour on robust control research is focused on those techniques which utilise the Variable Structure Control Method and Lyapunov's Second Method and which constitute the backbone of the so-called deterministic control of uncertain systems. The chapters of this book cover a large spectrum of the recent research and introduce the most innovative ideas in the field. Contained within the volume, the reader will find a survey of control Lyapunov functions, new structures of sliding mode controllers with discussion on higher order sliding modes, new techniques for the design of direct and indirect adaptive controllers, an introduction to the geometric theory of flat systems, controllers for plants with component-wise bounded inputs, robust design via linear matrix inequalities and polytopic covering, and some issues on the dissipativity and absolute stability of nonlinear systems.

*Robust Control Design: An Optimal Control Approach* Feng Lin, 2007-09-11 Based on research into an optimal control approach to robust control design, this book presents an approach that translates a robust control problem into its optimal control counterpart. It also offers both theoretical and practical applications, including flexible structure, robotics, and aircraft control. It is of interest to postgraduate students.

**Robust Control for Nonlinear Time-Delay Systems** Changchun Hua, Liulu Zhang, Xinping Guan, 2017-06-28 This book reports on the latest findings concerning nonlinear control theory and applications. It presents novel work on several kinds of commonly encountered nonlinear time delay systems.

including those whose nonlinear terms satisfy high order polynomial form or general nonlinear form those with nonlinear input or a triangular structure and so on As such the book will be of interest to university researchers R D engineers and graduate students in the fields of control theory and control engineering who wish to learn about the core principles methods algorithms and applications of nonlinear time delay systems

**1996 IEEE International Workshop on Variable Structure Systems, VSS '96** ,1996 VSS 96 was a workshop designed for control engineers working in the field of sliding mode control VSS and nonlinear systems Providing coverage of that workshop this text examines robust sliding mode VSS in power electronics time delay systems VSS theory and VSS applications

Robust Control of Uncertain Dynamic Systems  
Rama K. Yedavalli,2013-12-05 This textbook aims to provide a clear understanding of the various tools of analysis and design for robust stability and performance of uncertain dynamic systems In model based control design and analysis mathematical models can never completely represent the real world system that is being modeled and thus it is imperative to incorporate and accommodate a level of uncertainty into the models This book directly addresses these issues from a deterministic uncertainty viewpoint and focuses on the interval parameter characterization of uncertain systems Various tools of analysis and design are presented in a consolidated manner This volume fills a current gap in published works by explicitly addressing the subject of control of dynamic systems from linear state space framework namely using a time domain matrix theory based approach This book also Presents and formulates the robustness problem in a linear state space model framework Illustrates various systems level methodologies with examples and applications drawn from aerospace electrical and mechanical engineering Provides connections between lyapunov based matrix approach and the transfer function based polynomial approaches Robust Control of Uncertain Dynamic Systems A Linear State Space Approach is an ideal book for first year graduate students taking a course in robust control in aerospace mechanical or electrical engineering

*Robust Control Design 2003* Sergio Bittanti,Patrizio Colaneri,2004

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## **Table of Contents Robust Control Of Nonlinear Uncertain Systems**

1. Understanding the eBook Robust Control Of Nonlinear Uncertain Systems
  - The Rise of Digital Reading Robust Control Of Nonlinear Uncertain Systems
  - Advantages of eBooks Over Traditional Books
2. Identifying Robust Control Of Nonlinear Uncertain Systems
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Robust Control Of Nonlinear Uncertain Systems
  - User-Friendly Interface
4. Exploring eBook Recommendations from Robust Control Of Nonlinear Uncertain Systems
  - Personalized Recommendations
  - Robust Control Of Nonlinear Uncertain Systems User Reviews and Ratings
  - Robust Control Of Nonlinear Uncertain Systems and Bestseller Lists

5. Accessing Robust Control Of Nonlinear Uncertain Systems Free and Paid eBooks
  - Robust Control Of Nonlinear Uncertain Systems Public Domain eBooks
  - Robust Control Of Nonlinear Uncertain Systems eBook Subscription Services
  - Robust Control Of Nonlinear Uncertain Systems Budget-Friendly Options
6. Navigating Robust Control Of Nonlinear Uncertain Systems eBook Formats
  - ePub, PDF, MOBI, and More
  - Robust Control Of Nonlinear Uncertain Systems Compatibility with Devices
  - Robust Control Of Nonlinear Uncertain Systems Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Robust Control Of Nonlinear Uncertain Systems
  - Highlighting and Note-Taking Robust Control Of Nonlinear Uncertain Systems
  - Interactive Elements Robust Control Of Nonlinear Uncertain Systems
8. Staying Engaged with Robust Control Of Nonlinear Uncertain Systems
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Robust Control Of Nonlinear Uncertain Systems
9. Balancing eBooks and Physical Books Robust Control Of Nonlinear Uncertain Systems
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Robust Control Of Nonlinear Uncertain Systems
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Robust Control Of Nonlinear Uncertain Systems
  - Setting Reading Goals Robust Control Of Nonlinear Uncertain Systems
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Robust Control Of Nonlinear Uncertain Systems
  - Fact-Checking eBook Content of Robust Control Of Nonlinear Uncertain Systems
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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