Discrete Sliding Mode Control For Robust Tracking Of Time

Frequency-Shaped and Observer-Based Discrete-time Sliding Mode ControlSpringer

Sliding Mode Control (SMC) is gaining increasing importance as a universal design tool for the robust control of linear and nonlinear systems. The strengths of sliding mode controllers result from the ease and flexibility of the methodology for their design and implementation. They provide inherent order reduction, direct incorporation of robustness against system uncertainties and disturbances, and an implicit stability proof. They also allow for the design of high performance control systems at low costs. SMC is particularly useful for electro-mechanical systems because of its discontinuous structure. In fact, since the hardware of many electro-mechanical systems (such as electric motors) prescribes discontinuous inputs, SMC has become the natural choice for direct implementation. The book is intended primarily for engineers and establishes an interdisciplinary bridge between control science, electrical and mechanical engineering.

Focussing on the design of a specific control strategy using digital computers, this book explains a new robust LMI-based (state-feedback and observer-based output-feedback) DSMC (discrete-time sliding mode control) including a new scheme for sparsely distributed control. It also discusses recent investigations' output in the field of

This monograph investigates the existence of higher order sliding mode in discrete-time systems and propounds a new concept of discrete-time higher order sliding mode. The authors propose a definition of discrete-time higher order sliding mode and a control law is designed by means of a concept for an uncertain linear-time invariant system, as well as the behavior of the closed-loop system is analyzed. Moreover, the book includes a thorough treatment of the probabilistic and non-deterministic case, i.e. stochastic discrete-time higher order sliding mode. The target audience primarily comprises research experts in control theory but the book may also be beneficial for graduate students alike.

This book presents essential studies and applications in the context of sliding mode control, highlighting the latest findings from interdisciplinary theoretical studies, ranging from computational algorithm development to representative applications. Readers will learn how to easily tailor the techniques to accommodate their ad hoc applications. To make the content as accessible as possible, the book employs a clear route in each paper, moving from background to motivation, to quantitative development (equations), and lastly to case studies/illustrations/tutorials (simulations, experiences, curves, tables, etc.). Though primarily intended for graduate students, professors and researchers from related fields, the book will also benefit engineers and scientists from industry.

The main objective of this monograph is to present a broad range of well worked out, recent application studies as well as theoretical contributions in the field of sliding mode control system analysis and design. The contributions presented here include new theoretical developments as well as successful applications of variable structure controllers primarily in the field of power electronics, electric drives and motion steering systems. They enrich the current state of the art, and motivate and encourage new ideas and solutions in the sliding mode control area.

Nonlinear control theory has been successfully applied to continuous, nonlinear, autonomous plant models. Implementation of these continuous control laws, using digital computers, has relied upon high sample frequencies to approximate the performance of continuous control. This thesis extends the design of continuous sliding mode control to discrete and to sampled data systems. Continuous, nonlinear, autonomous, second order dynamic plant models are discretized using an approximation to a Taylor series expansion. The discretization process accounts for the Zero Order Hold circuit, used to convert the discrete control output of the digital computer, into a piecewise continuous control input to the plant. A Discrete Sliding Mode Control is developed using Feedback Linearization to account for plant model nonlinearities, and Lyapunov Stability analysis to guarantee convergence to the sliding manifold. A five step design process systematizes the design technique. The design technique was applied to two unstable nonlinear second order plant models. Stability was confirmed by simulation studies. Comparison with the Continuous Sliding Mode Control implemented digitally, at a sample rate five times the plant model fundamental frequency, showed that the Discrete Sliding Mode Control retained asymptotic stability while the Continuous Sliding Mode Control did not.

This book explores emerging methods and algorithms that enable precise control of micro-/nano-positioning systems. The text describes three control strategies: hysteresis-model-based feedforward control and hysteresis-model-free feedback control based on and free from state observation. Each paradigm receives dedicated attention within a particular part of the text. Readers are shown how to design, validate and apply a variety of new control approaches in micromanipulation: hysteresis modelling, discrete-time sliding-mode control and model-reference adaptive control. Experimental results are provided throughout and build up to a detailed treatment of practical applications in the fourth part of the book. The applications focus on control of piezoelectric grippers. Advanced Control of Piezoelectric Micro-/Nano-Positioning Systems will assist academic researchers and practising control and mechatronics engineers interested in suppressing sources of nonlinearity such as hysteresis and drift when combining position and force control of precision systems with piezoelectric actuation.

"Advanced Sliding Mode Control for Mechanical Systems: Design, Analysis and MATLAB Simulation" takes readers through the basic concepts, covering the most recent research in sliding mode control. The book is written from the perspective of practical engineering and examines numerous classical sliding mode controllers, including continuous time sliding mode control, discrete time sliding mode control, fuzzy sliding mode control, neural sliding mode control, backstepping sliding mode control, dynamic sliding mode control, sliding mode control based on observer, terminal sliding mode control, sliding mode control for robot manipulators, and sliding mode control for aircraft. This book is intended for engineers and researchers working in the field of control. Dr. Jinkun Liu works at Beijing University of Aeronautics and Astronautics and Dr. Xinhua Wang works at the National University of Singapore.

Sliding mode control is a simple and yet robust control technique, where the system states are made to confine to a selected subset. With the increasing use of computers and discrete-time samplers in controller implementation in the recent past, discrete-time systems and computer based control have become important topics. This monograph presents an output feedback sliding mode control philosophy which can be applied to almost all controllable and observable systems, while at the same time being simple enough as not to tax the computer too much. It is shown that the solution can be found in the synergy of the multirate output sampling concept and the concept of discrete-time sliding mode control.

This book presents the scientific outcomes of the International Conference AUTOMATION 2020, held on March 18–20, 2020 in Warsaw, Poland. The next 30 years will see radical innovations in production processes, transportation management and social life. The changes brought about by the transformation to zero-emission industry require advances in many fields, but especially in industrial automation, robotics and measurement techniques associated with the cyber-physical systems employing artificial intelligence that will be key to reducing costs and enabling European society to maintain its quality of live. In this context, the book features the latest research toward further developing these fields of engineering, and also offers solutions and guidelines that are useful for both researchers and engineers addressing problems associated with the world of ongoing radical changes.

This edited monograph provides a comprehensive and in-depth analysis of sliding mode control, focusing on event-triggered implementation. The technique allows to prefix the steady-state bounds of the system, and this is independent of any boundary disturbances. The idea of event-triggered SMC is developed for both single input / single output and multi-input / multi-output linear systems. Moreover, the reader learns how to apply this method to nonlinear systems. The book primarily addresses research experts in the field of sliding mode control, but the book may also be beneficial for graduate students.

This book extrapolates many of the concepts that are well defined for discrete-time deterministic sliding-mode control for use with discrete-time stochastic systems. It details sliding-function designs for various categories of linear time-invariant systems and its application for control. The resulting sliding-mode control addresses robustness issues and the functional-observer approach reduces the observer order substantially. Sliding-mode control (SMC) is designed for discrete-time stochastic systems, extended so that states lie within a specified band, and able to deal with incomplete information. Functional-observer-based SMC is designed for various clauses of stochastic systems: discrete-time; discrete-time with delay; state time-delayed; and those with parametric uncertainty. Stability considerations arising because of parametric uncertainty are taken into account and, where necessary, the effects of unmatched uncertainties mitigated. A simulation example is used to explain the use of the functional-observer approach to SMC design. Discrete-Time Stochastic Sliding-Mode Control Using Functional Observation will interest all researchers working in sliding-mode control and will be of particular assistance to graduate students in understanding the changes in design philosophy that arise when changing from continuous- to discrete-time systems. It helps to pave the way for further progress in applications of discrete-time SMC.

Sliding Mode Control of Switching Power Converters: Techniques and Implementation is perhaps the first in-depth account of how sliding mode controllers can be practically engineered to optimize control of power converters. A complete understanding of this process is timely and necessary, as the electronics industry moves toward the use of renewable energy sources and widely varying loads that can be adequately supported only by power converters using nonlinear controllers. Of the various advanced control methods used to handle the complex requirements of power conversion systems, sliding mode control (SMC) has been most widely investigated and proved to be a more feasible alternative than fuzzy and adaptive control for existing and future power converters. Bridging the gap between power electronics and control theory, this book employs a top-down instructional approach to discuss traditional and modern SMC techniques. Covering everything from equations to analog implantation, it: Provides a comprehensive general overview of SMC principles and methods Offers advanced readers a systematic exposition of the mathematical machineries and design principles relevant to construction of SMC, then introduces newer approaches Demonstrates the practical implementation and supporting design rules of SMC, based on analog circuits Promotes an appreciation of general nonlinear control by presenting it from a practical perspective and using familiar engineering terminology With specialized coverage of modeling and implementation that is useful to students and professionals in electrical and electronic engineering, this book clarifies SMC principles and their application to power converters. Making the material equally accessible to all readers, whether their background is in analog circuit design, power electronics, or control engineering, the authors—experienced researchers in their own right—elegantly and practically relate theory, application, and mathematical concepts and models to corresponding industrial targets.

This book presents few novel Discrete-time Sliding Mode (DSM) protocols for leader-following consensus of Discrete Multi-Agent Systems (DMASs). The protocols intend to achieve the consensus in finite time steps and also tackle the corresponding uncertainties. Based on the communication graph topology of multi-agent systems, the protocols are divided into two groups, namely (i) Fixed graph topology and (ii) Switching graph topology. The coverage begins with the design of Discrete-time Sliding Mode (DSM) protocols using Gao's reaching law and power rate reaching law for the synchronization of linear DMASs by using the exchange of information between the agents and the leader to achieve a common goal. Then, in a subsequent chapter, analysis for no. of fixed-time steps required for the leader-following consensus is presented. The book also includes chapters on the design of Discrete-time Higher-order Sliding Mode (DHSM) protocols, Event-triggered DSM protocols for the leader-following consensus of DMASs. A chapter is also included on the design of DHSM protocols for leader-following consensus of heterogeneous DMASs. Special emphasis is given to the practical implementation of each proposed DSM protocol for achieving leader-following consensus of helicopter systems, flexible joint robotic arms, and rigid joint robotic arms. This book offers a ready reference guide for graduate students and researchers working in the areas of control, automation, and communication engineering, and in particular the cooperative control of multi-agent systems. It will also benefit professional engineers working to design and implement robust controllers for power systems, autonomous vehicles, military surveillance, smartgrids/microgrids, vehicle traffic management, robotic teams, and aerial robots.

This book reports on the latest developments in sliding mode overhead crane control, presenting novel research ideas and findings on sliding mode control (SMC), hierarchical SMC and compensator design-based hierarchical sliding mode. The results, which were previously scattered across various journals and conference proceedings, are now presented in a systematic and unified form. The book will be of interest to researchers, engineers and graduate students in control engineering and mechanical engineering who want to learn the methods and applications of SMC.

This concise book covers modern sliding mode control theory. The authors identify key contributions defining the theoretical and applicative state-of-the-art of the sliding mode control theory and the most promising trends of the ongoing research activities.

This book compiles recent developments on sliding mode control theory and its applications. Each chapter presented in the book proposes new dimension in the sliding mode control theory such as higher order sliding mode control, event triggered sliding mode control, networked control, higher order discrete-time sliding mode control and sliding mode control for multi-agent systems. Special emphasis has been given to practical solutions to design involving new types of sliding mode control. This book is a reference guide for graduate students and researchers working in the domain for designing sliding mode controllers. The book is also useful to professional engineers working in the field to design robust controllers for various applications.

AfterasurveypaperbyUtkininthelate1970s,slidingmodecontrolmeth- ologies emerged as an e?ective tool to tackle uncertainty and disturbances which are inevitable in most of the practical systems. Sliding mode control is a particular class of variable structure control which was introduced by Emel'yanov and his colleagues. The design paradigms of sliding mode c- trol has now become a mature design technique for the design of robust c- troller of uncertain system. In sliding mode technique, the state trajectory of the system is constrained on a chosen manifold (or within some neighb- hood thereof) by an appropriatecontrolaction. This manifold is also called a switching surface or a sliding surface. During sliding mode, system dynamics is governed by the chosen manifold which results in a well celebrated inva- ance property towards certain classes of disturbance and model mismatches. The purpose of this monograph is to give a di?erent dimension to sl- ing surface design to achieve high performance of the system. Design of the switching surface is vital because the closed loop dynamics is governed by the parameters of the sliding surface. Therefore sliding surface should be - signed to meet the closed loop speci?cations. Many systems demand high performance with robustness. To address this issue of achieving high perf- mance with robustness, we propose nonlinear surfaces for di?erent classes of systems. The nonlinear surface is designed such that it changes the system's closed-loop

damping ratio from its initial low value to a ?nal high value.
Sliding Mode Control Using MATLAB provides many sliding mode controller design examples, along with simulation examples and MATLAB programs. Following the review of sliding mode control, the book includes sliding mode control for continuous systems, robust adaptive sliding mode control, sliding mode control for underactuated systems, backstepping, and dynamic surface sliding mode control, sliding mode control based on filter and observer, sliding mode control for discrete systems, fuzzy sliding mode control, neural network sliding mode control, and sliding mode control for robot manipulators. The contents of each chapter are independent, providing readers with information they can use for their own needs. It is suitable for the readers who work on mechanical and electronic engineering, electrical automation engineering, etc., and can also be used as a teaching reference for universities. Provides many sliding mode controller design examples to help readers solve their research and design problems Includes various, implementable, robust sliding mode control design solutions from engineering applications Provides the simulation examples and MATLAB programs for each sliding mode control algorithm
This book presents novel algorithms for designing Discrete-Time Sliding Mode Controllers (DSMCs) for Networked Control Systems (NCSs) with both types of fractional delays namely deterministic delay and random delay along with different packet loss conditions such as single packet loss and multiple packet loss that occur within the sampling period. Firstly, the switching type and non-switching type algorithms developed for the deterministic type fractional delay where the delay is compensated using Thiran's approximation technique. A modified discrete-time sliding surface is proposed to derive the discrete-time sliding mode control algorithms. The algorithm is further extended for the random fractional delay with single packet loss and multiple packet loss situations. The random fractional delay is modelled using Poisson's distribution function and packet loss is modelled by means of Bernoulli's function. The condition for closed loop stability in all above situations are derived using the Lyapunov function. Lastly, the efficacy of the proposed DSMC algorithms are demonstrated by extensive simulations and also experimentally validated on a servo system.
It is well established that the sliding mode control strategy provides an effective and robust method of controlling the deterministic system due to its well-known invariance property to a class of bounded disturbance and parameter variations. Advances in microcomputer technologies have made digital control increasingly popular among the researchers worldwide. And that led to the study of discrete-time sliding mode control design and its implementation. This brief presents, a method for multi-rate frequency shaped sliding mode controller design based on switching and non-switching type of reaching law. In this approach, the frequency dependent compensator dynamics are introduced through a frequency-shaped sliding surface by assigning frequency dependent weighing matrices in a linear quadratic regulator (LQR) design procedure. In this way, the undesired high frequency dynamics or certain frequency disturbance can be eliminated. The states are implicitly obtained by measuring the output at a faster rate than the control. It is also known that the vibration control of smart structure is a challenging problem as it has several vibratory modes. So, the frequency shaping approach is used to suppress the frequency dynamics excited during sliding mode in smart structure. The frequency content of the optimal sliding mode is shaped by using a frequency dependent compensator, such that a higher gain can be obtained at the resonance frequencies. The brief discusses the design methods of the controllers based on the proposed approach for the vibration suppression of the intelligent structure. The brief also presents a design of discrete-time reduced order observer using the duality to discrete-time sliding surface design. First, the duality between the coefficients of the discrete-time reduced order observer and the sliding surface design is established and then, the design method for the observer using Riccati equation is explained. Using the proposed method, the observer for the Power System Stabilizer (PSS) for Single Machine Infinite Bus (SMIB) system is designed and the simulation is carried out using the observed states. The discrete-time sliding mode controller based on the proposed reduced order observer design method is also obtained for a laboratory experimental servo system and verified with the experimental results.
This book describes the advances and applications in Sliding mode control (SMC) which is widely used as a powerful method to tackle uncertain nonlinear systems. The book is organized into 21 chapters which have been organised by the editors to reflect the various themes of sliding mode control. The book provides the reader with a broad range of material from first principles up to the current state of the art in the area of SMC and observation presented in a clear, matter-of-fact style. As such it is appropriate for graduate students with a basic knowledge of classical control theory and some knowledge of state-space methods and nonlinear systems. The resulting design procedures are emphasized using Matlab/Simulink software.
This is Volume II of a three volume set constituting the refereed proceedings of the Third International Symposium on Neural Networks, ISNN 2006. 616 revised papers are organized in topical sections on neurobiological analysis, theoretical analysis, neurodynamic optimization, learning algorithms, model design, kernel methods, data preprocessing, pattern classification, computer vision, image and signal processing, system modeling, robotic systems, transportation systems, communication networks, information security, fault detection, financial analysis, bioinformatics, biomedical and industrial applications, and more.
This book examines the different spatial control techniques for regulation of spatial power distribution in advanced heavy water reactors (AHWR). It begins with a review of the literature pertinent to the modeling and control of large reactors. It also offers a nodal-core model based on finite difference approximation since the AHWR core is considered to be divided into 17 relatively large nodes. Further, it introduces a nonlinear model characterizing important thermal hydraulics parameters of AHWR and integrates it into the neutronics model to obtain a coupled neutronics-thermal hydraulics model of AHWR. The book also presents a vectorized nonlinear model of AHWR and implements it in MATLAB/Simulink environment. The model of the reactor is then linearized at the rated power and put into standard state variable form. It is characterized by 90 states, 5 inputs and 18 outputs. Lastly, it discusses control techniques for a nonlinear model of AHWR. This book will prove to be a valuable resource for professional engineers and implementation specialists, researchers and students.
The main purpose of control engineering is to steer the regulated plant in such a way that it operates in a required manner. The desirable performance of the plant should be obtained despite the unpredictable influence of the environment on the control system and no matter if the plant parameters are precisely known. Even though the parameters may change with time and load, still the system should preserve its nominal properties and ensure the required behavior of the plant. In other words, the principal objective of control engineering is to design systems that are robust with respect to external disturbances and modeling uncertainty. This objective may be very well achieved using the sliding mode technique, which is the subject of this book.
The sliding mode control paradigm has become a mature technique for the design of robust controllers for a wide class of systems including nonlinear, uncertain and time-delayed systems. This book is a

collection of plenary and invited talks delivered at the 12th IEEE International Workshop on Variable Structure System held at the Indian Institute of Technology, Mumbai, India in January 2012. After the workshop, these researchers were invited to develop book chapters for this edited collection in order to reflect the latest results and open research questions in the area. The contributed chapters have been organized by the editors to reflect the various themes of sliding mode control which are the current areas of theoretical research and applications focus; namely articulation of the fundamental underpinning theory of the sliding mode design paradigm, sliding modes for decentralized system representations, control of time-delay systems, the higher order sliding mode concept, results applicable to nonlinear and underactuated systems, sliding mode observers, discrete sliding mode control together with cutting edge research contributions in the application of the sliding mode concept to real world problems. This book provides the reader with a clear and complete picture of the current trends in Variable Structure Systems and Sliding Mode Control Theory.