

# Discrete-Time Sliding Mode Control for Robot Manipulators<sup>†</sup>

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**Abstract** In the real-field of control cases for robot manipulators, there always exists a modeling error, which results the model has the uncertainties in its parameters and/or structure. In many modern applications, digital computers are extensively used to implement control algorithms to control such systems. The discretization of the nonlinear dynamic equations of such systems results in a complicated discrete dynamic equations. Therefore, it will be difficult to design a discrete-time controller to give good tracking performances in the presence of certain uncertainties. In this paper, a discrete-time sliding mode control algorithm for nonlinear and time varying robot manipulators with uncertainties is presented. Sufficient conditions for guaranteeing the convergence of the discrete-time SMC system are derived. As example simulations, the proposed SMC algorithm is applied to a two-link robotic manipulator with unknown dynamics. The results of the simulation indicate that the developed control scheme is effective in manipulators and electro-mechanical system control.

**Key Words:** Sliding Mode Control(SMC), Discrete-time Controller, Robot Manipulator

## 1. INTRODUCTION

In recent years, methodology known as *sliding mode control* (SMC) has been researched actively, and the sliding mode control has effectively used in the tracking control of robot manipulators by many researchers[1,2,4-7,9,11-13]. The concept of sliding mode control has been studied in detail in Utkin [10], where it has been used to stabilize a class of non-linear systems. However, most of the related works [2,4,7,8] were based on the manipulator continuous-time linear parameterization model, which is a linear equation in terms of the unknown or unprecisely known parameter vector. In addition,

most continuous-time control laws require a large amount of computation.

The discretization of the nonlinear dynamic equations of such systems results in a complicated discrete dynamic equations. Therefore, it will be difficult to design a discrete-time controller to give good tracking performances in the presence of certain uncertainties. Whereas, the digital control algorithm is usually very simple and can be easily implemented on-line using microcomputers, so it is predominantly more effective in actual application. But only a few literatures [1,3,5,6] have studied the manipulator discrete-time model and discrete-time control so far.

In this paper, based on the continuous-time SMC theory[8,10,14,15,16], when the sample time is small enough, the manipulator dynamic model is equivalent to a 2 order discrete-time equation whose

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# A New Algorithm For Discrete Time Sliding Mode Control

**Mooncheol Won**



## **A New Algorithm For Discrete Time Sliding Mode Control:**

**Advances in Discrete-Time Sliding Mode Control** Ahmadreza Argha, Steven Su, Li Li, Hung Tan Nguyen, Branko George Celler, 2018-06-14 The focus of this book is on the design of a specific control strategy using digital computers This control strategy referred to as Sliding Mode Control SMC has its roots in continuous time relay control This book aims to explain recent investigations output in the field of discrete time sliding mode control DSMC The book starts by explaining a new robust LMI based state feedback and observer based output feedback DSMC including a new scheme for sparsely distributed control It includes a novel event driven control mechanism called actuator based event driven scheme using a synchronized rate biofeedback system for heart rate regulation during cycle ergometer Key Features Focuses on LMI based SMC sliding mode control for uncertain discrete time system using novel nonlinear components in the control law Makes reader understand the techniques of designing a discrete controller based on the flexible sliding functions Proposes new algorithms for sparsifying control and observer network through multi objective optimization frameworks Discusses a framework for the design of SMC for two dimensional systems along with analyzing the controllability of two dimensional systems Discusses novel schemes for sparsifying the control network

**Discrete-Time Higher Order Sliding Mode** Nalin Kumar Sharma, Janardhanan Sivaramakrishnan, 2018-09-10 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

**Advances in Sliding Mode Control** B Bandyopadhyay, S Janardhanan, Sarah K. Spurgeon, 2013-03-15 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 Emerging Trends in Sliding Mode Control Axaykumar Mehta, Bijnan Bandyopadhyay, 2020-12-21 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 Advances in Neural Networks - ISNN 2006 Jun Wang, Zhang Yi, Jacek M. Zurada, Bao-Liang Lu, Yin Hujun, 2006-05-10 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 Systems Thinking Approach for Social Problems Vivek Vijay, Sandeep Kumar Yadav, Bibhas Adhikari, Harinipriya Seshadri, Deepak Kumar Fulwani, 2015-01-05 The book is a collection of peer reviewed scientific papers submitted by active researchers in the 37th National System Conference NSC 2013 NSC is an annual event of the Systems Society of India SSI primarily oriented to strengthen the systems movement and its applications for the welfare of humanity A galaxy of academicians professionals scientists statesman and researchers from different parts of the country and abroad are invited to attend the conference The book presents research articles in the areas of system s modelling complex network modelling cyber security sustainable systems design health care systems socio economic systems and clean and green technologies The book can be used as a tool for further research **Discrete-time Sliding Mode Control B.** Bandyopadhyay, S. Janardhanan, 2005-10-17 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 Recent Advances in Electrical Engineering and Control Applications Mohammed Chadli, Sofiane Bououden, Ivan Zelinka, 2016-12-01 This book of proceedings includes papers presenting the state of art in electrical

engineering and control theory as well as their applications The topics focus on classical as well as modern methods for modeling control identification and simulation of complex systems with applications in science and engineering The papers were selected from the hottest topic areas such as control and systems engineering renewable energy faults diagnosis faults tolerant control large scale systems fractional order systems unconventional algorithms in control engineering signals and communications The control and design of complex systems dynamics analysis and modeling of its behavior and structure is vitally important in engineering economics and in science generally science today Examples of such systems can be seen in the world around us and are a part of our everyday life Application of modern methods for control electronics signal processing and more can be found in our mobile phones car engines home devices like washing machines is as well as in such advanced devices as space probes and systems for communicating with them All these technologies are part of technological backbone of our civilization making further research and hi tech applications essential The rich variety of contributions appeals to a wide audience including researchers students and academics

**Proceedings of the ... IEEE International Conference on Control Applications** ,1996      **Proceedings of the ... American Control Conference** ,2005

**Advanced, Contemporary Control** Andrzej Bartoszewicz,Jacek Kabziński,Janusz Kacprzyk,2020-06-24 This book presents the proceedings of the 20th Polish Control Conference A triennial event that was first held in 1958 the conference successfully combines its long tradition with a modern approach to shed light on problems in control engineering automation robotics and a wide range of applications in these disciplines The book presents new theoretical results concerning the steering of dynamical systems as well as industrial case studies and worked solutions to real world problems in contemporary engineering It particularly focuses on the modelling identification analysis and design of automation systems however it also addresses the evaluation of their performance efficiency and reliability Other topics include fault tolerant control in robotics automated manufacturing mechatronics and industrial systems Moreover it discusses data processing and transfer issues covering a variety of methodologies including model predictive robust and adaptive techniques as well as algebraic and geometric methods and fractional order calculus approaches The book also examines essential application areas such as transportation and autonomous intelligent vehicle systems robotic arms mobile manipulators cyber physical systems electric drives and both surface and underwater marine vessels Lastly it explores biological and medical applications of the control theory inspired methods

Variable-Structure Approaches Andreas Rauh,Luise Senkel,2016-05-17 This edited book aims at presenting current research activities in the field of robust variable structure systems The scope equally comprises highlighting novel methodological aspects as well as presenting the use of variable structure techniques in industrial applications including their efficient implementation on hardware for real time control The target audience primarily comprises research experts in the field of control theory and nonlinear dynamics but the book may also be beneficial for graduate students

**Discrete-Time Sliding Mode Control for Networked Control System** Dipesh H. Shah,Axaykumar

Mehta,2018-03-16 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 Proceedings of the IEEE International

Symposium on Industrial Electronics ,2005 Discrete-Time Stochastic Sliding Mode Control Using Functional Observation  
Satnesh Singh,S. Janardhanan,2019-11-25 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 classes 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

*Conference Record, Industry Applications Society, IEEE-IAS Annual Meeting (1981)* IEEE Industry Applications Society,1999 **IECON '94: Plenary session, power electronics** ,1994 *Multiple Surface Sliding Control with Application to Engine Control* Mooncheol Won,1995 **Journal of Dynamic Systems, Measurement, and Control** ,2004 Publishes theoretical and applied original papers in dynamic systems Theoretical papers present new theoretical developments and knowledge for controls of dynamical systems together with clear engineering motivation for the new theory Applied papers include modeling simulation and corroboration of theory with emphasis on demonstrated practicality  
*7th International Workshop on Advanced Motion Control 2002* ,2002

## Unveiling the Magic of Words: A Report on "A New Algorithm For Discrete Time Sliding Mode Control"

In some sort of defined by information and interconnectivity, the enchanting power of words has acquired unparalleled significance. Their capability to kindle emotions, provoke contemplation, and ignite transformative change is truly awe-inspiring. Enter the realm of "A New Algorithm For Discrete Time Sliding Mode Control," a mesmerizing literary masterpiece penned by a distinguished author, guiding readers on a profound journey to unravel the secrets and potential hidden within every word. In this critique, we shall delve in to the book is central themes, examine its distinctive writing style, and assess its profound impact on the souls of its readers.

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