IEEE Access

Date of publication xxxx 00, 0000, date of current version xxxx 00, 0000.

Digital Object Identifier 10.1109/ACCESS.2022.0123213

Observer-based model-free adaptive sliding mode predictive control

BING REN[1,2], GUANGQING BAO[3]

[1]School of Automation, Electrical Engineering, Lanzhou Jiaotong University, Lanzhou 730070, China.
[2]College of Electrical Information Engineering, Lanzhou University of Technology, Lanzhou 730050, China.
[3]School of Electronics & Information Engineering, Southwest Petroleum University, Chengdu

Corresponding author: Bing Ren (e-mail: ice84_0@163.com).

This research was funded by National Natural Science Foundation of China (51907012), Key Research and Development Program of Gansu Province (20YFGA055), Natural Science Foundation of Gansu Province (22JR5RA359) and Youth Foundation of Lanzhou Jiaotong University (2019034).

ABSTRACT This paper proposes a new observer-based model-free adaptive sliding mode predictive control method (MFASPC) for discrete-time nonlinear systems. This scheme first equates the discrete-time nonlinear system to a linear form using a data-driven compact form dynamic linearization (CFDL) technique, establishes a data model consisting of only the pseudo partial derivatives (PPD), input data and output data, designs adaptive observers to achieve the estimation of the unknown PPD. The controller design part uses integral sliding mode control (SMC) to ensure the system's robustness. In contrast, with its constraint characteristics, the model predictive control (MPC) replaces the traditional switching control of SMC. The closed-loop control quantities are obtained by solving a rolling optimization problem in the finite time domain to provide dynamic optimal control action. The theoretical derivation of the Lyapunov function is used to demonstrate the system's stability. In order to verify the effectiveness of the proposed algorithm, numerical simulations and Photovoltaic power generation system simulation experiments are conducted, respectively, and the results show that the proposed control algorithm has a very reliable tracking capability and control accuracy.

INDEX TERMS Adaptive observer, model free, sliding mode predictive control, rolling optimization, data-driven

I. INTRODUCTION

In recent years, adaptive control techniques for nonlinear systems have attracted a large number of scholars and much effort has been devoted to them [1]–[3]. However, most methods require dynamical or mechanistic analysis of the control system to obtain an accurate mathematical model first, and there are inevitably approximation links throughout the process [4]. In contrast, the ignored unmodeled dynamics part may be a potential factor that makes the closed-loop system unstable and reduces the controller performance.

Model-free adaptive control (MFAC) is a data-driven control method for discrete-time nonlinear systems to improve modeling difficulties [5], and its most important features compared to other data-driven control methods are the equivalent dynamic linearization process and the introduction of virtual parameters (PPD). MFAC uses the input and output data of the system to update the virtual parameters online dynamically, thus establishing an equivalent data model, both the PPD and the data model, which depend merely on the data and are unrelated to the structural information of the system, thus thoroughly characterizing the nonlinear and uncertain features of the system [6]. It has been widely used in the past few years, such as urban traffic control, heading control, zero-sum game control, flexible joint control, etc. [7]–[10].

As the research progresses, to further solve the uncertainty problem of the control system and ensure robust performance in control, some scholars bring the SMC into the MFAC algorithm to carry out the research, which produces the model-free adaptive sliding mode control (MFASC) scheme. Among them, the sliding phase of the SMC law ensures the excellent stability performance of the system, and the arrival phase determines the system's dynamic performance. For example, [11]

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Aircraft Manufacturing, Safety and Control Melih Kuşhan,Seyid Fehmi Diltemiz,2025-12-03 Aircraft Manufacturing Safety and Control is a concise practice oriented guide to how modern aeroplanes are conceived built certified and kept safe in service Bridging design production and operations the volume introduces core methods in manufacturing metallic and composite processes bonding and fastening tolerance management non destructive inspection digital manufacturing Industry 4 0 producibility and cost alongside safety and airworthiness thinking regulatory compliance reliability and risk assessment damage tolerance maintenance human factors continued airworthiness It also connects these themes to flight and control systems guidance navigation and control fly by wire fault detection and isolation health monitoring and emerging autonomy showing how control architecture verification and safety assurance inform manufacturing choices With clear definitions process insights and worked examples the book helps engineers and managers translate requirements into robust products and repeatable factory practices Emphasis on sustainability lightweight structures energy efficient processes repairability and on data driven decision making prepares readers for the next generation of aircraft programs Written for students practitioners and leaders this cross disciplinary reference offers ready to apply concepts checklists and reasoning pathways that reduce risk improve quality and shorten time to market while strengthening safety from the first drawing to the last flight Mathematical Computing and Sustainability Shalli Rani,Syed Hassan Shah,Ayush Dogra,2025-10-20 The book is likely intended to provide a thorough knowledge of the complex relationships between computational intelligence mathematical computing and sustainability By taking an interdisciplinary approach the author may strive to connect theoretical frameworks with practical applications providing readers with a road map for navigating the intricacies of addressing long term difficulties The book could use case studies and examples to demonstrate how cutting edge technologies and mathematical models can be used to analyse and solve real world sustainability problems ultimately encouraging a holistic approach that fosters innovative solutions based on computational and mathematical principles This book is planned to cover the comprehensive investigation into the synergies between Computational Intelligence CI Mathematical Computing and Sustainability An examination of the possible impact of intelligent systems on sustainability new concepts and approaches for incorporating CI and mathematical computing into sustainable practices etc There will be chapters explaining the Exploration of upcoming technologies e g quantum computing bio inspired computing and their potential role in promoting sustainability **Disturbance Observer-Based Control** Shihua Li,Jun Yang,Wen-Hua Chen,Xisong Chen,2016-04-19 Due to its abilities to compensate disturbances and uncertainties disturbance observer based control DOBC is regarded as one of the most promising approaches for disturbance attenuation One of the first books on DOBC Disturbance Observer Based Control Methods and Applications presents novel theory results as well as best practices for applica **Robust Model Predictive Control and Receding Horizon Based Observer for a Brushless DC Drive**

Hua Liang Zhuang,2000 Model Predictive Control Ridong Zhang,Anke Xue,Furong Gao,2018-08-14 This monograph introduces the authors work on model predictive control system design using extended state space and extended non minimal state space approaches It systematically describes model predictive control design for chemical processes including the basic control algorithms the extension to predictive functional control constrained control closed loop system analysis model predictive control optimization based PID control genetic algorithm optimization based model predictive control and industrial applications Providing important insights useful methods and practical algorithms that can be used in chemical process control and optimization it offers a valuable resource for researchers scientists and engineers in the field of process system engineering and control engineering *Model Predictive Control with Fault Detection and Diagnosis for Multivariable Systems* Vinayak Deshpande,2022 The feedback control system design technique of Model Predictive Control MPC has been vastly used in the chemical and process engineering industry due to its ability to handle dynamics with multiple inputs and multiple outputs which are essentially the majority of today s engineering systems In addition the field of Fault Detection and Diagnosis FDD in control systems also has been extensively researched over the past decades as it is critical for the controller to realize when and if a fault has occurred within a system However due to the high computational requirements it is often challenging to implement FDD based MPC algorithms in resource limited real world systems This thesis addresses the development of MPC algorithms with combined state and fault estimation Firstly a novel Quadratic Programming QP formulation is developed for a recently proposed efficient MPC method along with simultaneous state and fault estimation Another contribution is the enhancement of a standard integral action MPC algorithm which has an implicit fault tolerance capability to provide state and actuator fault estimation in real time This work focuses on faults which are modeled as a Loss Of Effectiveness LOE The algorithm to estimate the system faults and states simultaneously is a simple observer based method which can be tuned beforehand thus eliminating the need for on line real time complex calculations Lastly a third contribution of this thesis is the application of the above methods to design MPC based flight control systems for fixed wing aircraft Simulations are presented to demonstrate the effectiveness of the proposed methods **Model Predictive Control** Basil Kouvaritakis,Mark Cannon,2015-12-01 For the first time a textbook that brings together classical predictive control with treatment of up to date robust and stochastic techniques Model Predictive Control describes the development of tractable algorithms for uncertain stochastic constrained systems The starting point is classical predictive control and the appropriate formulation of performance objectives and constraints to provide guarantees of closed loop stability and performance Moving on to robust predictive control the text explains how similar guarantees may be obtained for cases in which the model describing the system dynamics is subject to additive disturbances and parametric uncertainties Open and closed loop optimization are considered and the state of the art in computationally tractable methods based on uncertainty tubes presented for systems with additive model uncertainty Finally the tube framework is also applied to model

predictive control problems involving hard or probabilistic constraints for the cases of multiplicative and stochastic model uncertainty The book provides extensive use of illustrative examples sample problems and discussion of novel control applications such as resource allocation for sustainable development and turbine blade control for maximized power capture with simultaneously reduced risk of turbulence induced damage Graduate students pursuing courses in model predictive control or more generally in advanced or process control and senior undergraduates in need of a specialized treatment will find Model Predictive Control an invaluable guide to the state of the art in this important subject For the instructor it provides an authoritative resource for the construction of courses *Recent Advances in Model Predictive Control* Timm Faulwasser,Matthias A. Müller,Karl Worthmann,2021-04-17 This book focuses on distributed and economic Model Predictive Control MPC with applications in different fields MPC is one of the most successful advanced control methodologies due to the simplicity of the basic idea measure the current state predict and optimize the future behavior of the plant to determine an input signal and repeat this procedure ad infinitum and its capability to deal with constrained nonlinear multi input multi output systems While the basic idea is simple the rigorous analysis of the MPC closed loop can be quite involved Here distributed means that either the computation is distributed to meet real time requirements for very large scale systems or that distributed agents act autonomously while being coupled via the constraints and or the control objective In the latter case communication is necessary to maintain feasibility or to recover system wide optimal performance The term economic refers to general control tasks and thus goes beyond the typically predominant control objective of set point stabilization Here recently developed concepts like strict dissipativity of optimal control problems or turnpike properties play a crucial role The book collects research and survey articles on recent ideas and it provides perspectives on current trends in nonlinear model predictive control Indeed the book is the outcome of a series of six workshops funded by the German Research Foundation DFG involving early stage career scientists from different countries and from leading European industry stakeholders **Optimization-based Tuning of Nonlinear Model Predictive Control with State Estimation** E. Ali,E. Zafiriou,1993 Design of Observer-based Compensators Peter Hippe,Joachim Deutscher,2009-05-14 Design of Observer based Compensators facilitates and adds transparency to design in the frequency domain which is not as well established among control engineers as time domain design The presentation of the design procedures starts with a review of the time domain results therefore the book also provides quick access to state space methods for control system design Frequency domain design of observer based compensators of all orders is covered The design of decoupling and disturbance rejecting controllers is presented and solutions are given to the linear quadratic and the model matching problems The pole assignment design is facilitated by a new parametric approach in the frequency domain Anti windup control is also investigated in the framework of the polynomial approach The discrete time results for disturbance rejection and linear quadratic control are also presented The book contains worked examples that can easily be reproduced by the reader and the

results are illustrated by simulations **Developments in Model-Based Optimization and Control** Sorin Olaru,Alexandra Grancharova,Fernando Lobo Pereira,2015-12-23 This book deals with optimization methods as tools for decision making and control in the presence of model uncertainty It is oriented to the use of these tools in engineering specifically in automatic control design with all its components analysis of dynamical systems identification problems and feedback control design Developments in Model Based Optimization and Control takes advantage of optimization based formulations for such classical feedback design objectives as stability performance and feasibility afforded by the established body of results and methodologies constituting optimal control theory It makes particular use of the popular formulation known as predictive control or receding horizon optimization The individual contributions in this volume are wide ranging in subject matter but coordinated within a five part structure covering material on complexity and structure in model predictive control MPC collaborative MPC distributed MPC optimization based analysis and design and applications to bioprocesses multivehicle systems or energy management The various contributions cover a subject spectrum including inverse optimality and more modern decentralized and cooperative formulations of receding horizon optimal control Readers will find fourteen chapters dedicated to optimization based tools for robustness analysis and decision making in relation to feedback mechanisms fault detection for example and three chapters putting forward applications where the model based optimization brings a novel perspective Developments in Model Based Optimization and Control is a selection of contributions expanded and updated from the Optimisation based Control and Estimation workshops held in November 2013 and November 2014 It forms a useful resource for academic researchers and graduate students interested in the state of the art in predictive control Control engineers working in model based optimization and control particularly in its bioprocess applications will also find this collection instructive *Model Predictive Control* Eduardo F. Camacho,Carlos Bordons,2004-06-16 The second edition of Model Predictive Control provides a thorough introduction to theoretical and practical aspects of the most commonly used MPC strategies It bridges the gap between the powerful but often abstract techniques of control researchers and the more empirical approach of practitioners The book demonstrates that a powerful technique does not always require complex control algorithms Many new exercises and examples have also been added throughout Solutions available for download from the authors website save the tutor time and enable the student to follow results more closely even when the tutor isn t present **Handbook of Model Predictive Control** Saša V. Raković,William S. Levine,2018-09-01 Recent developments in model predictive control promise remarkable opportunities for designing multi input multi output control systems and improving the control of single input single output systems This volume provides a definitive survey of the latest model predictive control methods available to engineers and scientists today The initial set of chapters present various methods for managing uncertainty in systems including stochastic model predictive control With the advent of affordable and fast computation control engineers now need to think about using computationally intensive controls so the second part of

this book addresses the solution of optimization problems in real time for model predictive control The theory and applications of control theory often influence each other so the last section of Handbook of Model Predictive Control rounds out the book with representative applications to automobiles healthcare robotics and finance The chapters in this volume will be useful to working engineers scientists and mathematicians as well as students and faculty interested in the progression of control theory Future developments in MPC will no doubt build from concepts demonstrated in this book and anyone with an interest in MPC will find fruitful information and suggestions for additional reading **Trajectory tracking, path following, and learning in model predictive control** Fabian Russell Pfitz,2023-08-21 In this thesis we present novel model predictive control MPC formulations based on a convex open loop optimal control problem to tackle the problem setup of trajectory tracking and path following as well as the control of systems with unknown system dynamic In particular we consider the framework of relaxed barrier function based MPC rbMPC We extend the existing stability theory to the trajectory tracking and the path following problem We establish important system theoretic properties like closed loop stability and exact constraint satisfaction under suitable assumptions Moreover we evaluate the developed MPC algorithms in the area of automated driving in simulations as well as in a real world driving scenario Further we consider the control of completely unknown systems based on online optimization We divide the overall problem into the design of an estimation algorithm and a control algorithm The control algorithm is a model independent receding horizon control algorithm in which important system theoretic properties like convergence to the origin are guaranteed without the knowledge of the true system parameters The estimation and control algorithm are combined together and convergence to the origin of the closed loop system for fully unknown linear time invariant discrete time systems is shown Distributed Model Predictive Control with Event-Based Communication Dominic Groß,2014 *Gradient-based Nonlinear Model Predictive Control with Constraint Transformation for Fast Dynamical Systems* Bartosz Maciej Käpernick,2016 **Model Predictive Control** Eduardo F. Camacho,Carlos Bordons Alba,2013-12-19 This project thesis provides a brief overview of Model Predictive Control MPC A brief history of industrial model predictive control technology has been presented first followed by a some concepts like the receding horizon moves etc which form the basis of the MPC It follows the Optimization problem which ultimately leads to the description of the Dynamic Matrix Control DMC The MPC presented in this report is based on DMC After this the application summary and the limitations of the existing technology has been discussed and the next generation MPC with an emphasis on potential business and research opportunities has been reviewed Finally in the last part we generate Matlab code to implement basic model predictive controller and introduce noise into the model We have also taken up some case studies like Swimming pool water temperature control and helicopter flight control etc by applying the MPC controller on these models *Model Predictive Control for Nonlinear Networked Control Systems* Paolo Varutti,2014 **Data-driven Subspace-based Model Predictive Control** Noor Azizi Mardi,2010 *Advanced Model Predictive*

Control Bianca Lupei,2016 Model predictive control is an advanced method of process control that has been in use in the process industries in chemical plants and oil re neries since the 1980s In recent years it has also been used in power system balancing models Model predictive controllers rely on dynamic models of the process most often linear empirical models obtained by system identi cation The main advantage of model predictive control is the fact that it allows the current timeslot to be optimized while keeping future timeslots in account This is achieved by optimizing a nite time horizon but only implementing the current timeslot Model predictive control has the ability to anticipate future events and can take control actions accordingly MPC models predict the change in the dependent variables of the modelled system that will be caused by changes in the independent variables In a chemical process independent variables that can be adjusted by the controller are often either the setpoints of regulatory PID controllers or the nal control element Independent variables that cannot be adjusted by the controller are used as disturbances Dependent variables in these processes are other measurements that represent either control objectives or process constraints The book entitled Advanced Model Predictive Control is intended to present the readers the recent achievements in this eld The book also delivers applications of MPC in modern industry and e ective commercial software for MPC is familiarized

The Top Books of the Year Observer Based Model Predictive Control Researchgate The year 2023 has witnessed a noteworthy surge in literary brilliance, with numerous compelling novels enthralling the hearts of readers worldwide. Lets delve into the realm of bestselling books, exploring the captivating narratives that have charmed audiences this year. The Must-Read : Colleen Hoovers "It Ends with Us" This touching tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover expertly weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can succeed. Uncover the Best : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This spellbinding historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids absorbing storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Observer Based Model Predictive Control Researchgate : Delia Owens "Where the Crawdads Sing" This captivating coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens crafts a tale of resilience, survival, and the transformative power of nature, captivating readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of compelling stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a masterful and thrilling novel that will keep you wondering until the very end. The novel is a cautionary tale about the dangers of obsession and the power of evil.

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