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Observer-based model-free adaptive sliding mode predictive control

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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 (MFASMC) 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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Table of Contents Observer Based Model Predictive Control Researchgate

1. Understanding the eBook Observer Based Model Predictive Control Researchgate
 - The Rise of Digital Reading Observer Based Model Predictive Control Researchgate
 - Advantages of eBooks Over Traditional Books
2. Identifying Observer Based Model Predictive Control Researchgate
 - 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 Observer Based Model Predictive Control Researchgate
 - User-Friendly Interface
4. Exploring eBook Recommendations from Observer Based Model Predictive Control Researchgate
 - Personalized Recommendations
 - Observer Based Model Predictive Control Researchgate User Reviews and Ratings
 - Observer Based Model Predictive Control Researchgate and Bestseller Lists

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