

Abstract

This thesis introduces a comprehensive framework of novel data-driven discrete-time sliding mode control (DSMC) techniques tailored for discrete-time systems (DTS) subjected to disturbances and uncertainties, with a focus on both theoretical rigor and practical applicability. The central methodology leverages compact form dynamic linearization (CFDL) to construct control-oriented models using only input-output (I/O) data, thereby eliminating the need for explicit state-space modeling or system identification.

The primary contribution lies in the development of the CFDL-DSMC strategy, which integrates CFDL with a Minimum Operator-Based Discrete Sliding Mode Control (MDSMC) scheme. This formulation enhances disturbance rejection and tracking accuracy while ensuring robust stability, without relying on traditional switching gains that typically induce chattering. Stability analysis confirms that the proposed control law guarantees finite-time convergence of the sliding variable despite system uncertainties.

To address prescribed performance constraints (PPC) in data-driven control, the thesis introduces a transformative error mapping function that converts constrained tracking errors into an unconstrained domain. Based on this transformation and using Full Form Dynamic Linearization (FFDL), new MDSMC laws are formulated to ensure that the original tracking error converges within an asymmetric, user-defined boundary in a pre-defined finite time. This controller maintains a simple structure and avoids the need for additional switching elements, distinguishing it from conventional DSMC approaches.

Furthermore, a Multi-Rate Output Feedback (MROF)-based DSMC is developed, employing fast output sampling and minimum-operator-based reaching laws (RL), relying solely on output measurements and eliminating the need for full-state feedback. This approach is particularly advantageous in practical settings where full state information is inaccessible. Additionally, a finite-time minimum-operator-based controller is proposed to enhance response speed and guarantee settling time, thereby supporting real-time im-

plementation.

An adaptive reaching law is also introduced, utilizing both minimum and ceiling operators, enabling dynamic adjustment of control gains in response to uncertainties and matched disturbances. This law ensures convergence to the sliding surface within a user-specified time frame and eliminates chattering in the sliding phase by employing a non-switching-type sliding motion definition.

The versatility and robustness of the proposed methods are demonstrated through a series of simulations and experimental validations on various nonlinear discrete-time systems:

- A two-tank water level control system demonstrating real-time tracking accuracy and implementation feasibility.
- A single-link robotic manipulator validating robustness and performance under nonlinear dynamic conditions.
- A two-degree-of-freedom (2-DOF) helicopter system illustrating finite-time attitude tracking for both pitch and yaw axes using recursive backstepping integrated with the minimum operator.
- A magnetic levitation system (MLS) highlighting the method’s capability to achieve precise finite-time stabilization while significantly mitigating chattering.

Collectively, these contributions offer robust, efficient, and practically implementable solutions to control challenges in uncertain nonlinear discrete-time systems. The approaches developed herein address key limitations of traditional sliding mode control—such as chattering, reliance on full-state information, and lack of settling time control—while ensuring theoretical guarantees and strong practical performance in real-world applications.