Ruizhuo SONG, Shi XING, Zhen XU, 2022. Finite-time leader-follower consensus of a discrete-time system via sliding mode control. *Frontiers of Information Technology & Electronic Engineering*, 2022 23(7):1057-1068. https://doi.org/10.1631/FITEE.2100565

Finite-time leader-follower consensus of a discrete-time system via sliding mode control

Key words: Finite-time; Leader-follower consensus; Adaptive sliding mode control; Multi-agent systems

Ruizhuo SONG
E-mail: ruizhuosong@ustb.edu.cn

ORCID: https://orcid.org/0000-0002-6693-2738

Abstract

- In this study, we solve the finite-time leader-follower consensus problem of discrete-time second-order multi-agent systems (MASs) under the constraints of external disturbances. First, a novel consensus scheme is designed using a novel adaptive sliding mode control theory. Our adaptive controller is designed using the traditional sliding mode reaching law, and its advantages are chatter reduction and invariance to disturbances. In addition, the finite-time stability is demonstrated by presenting a discrete Lyapunov function. Finally, simulation results are presented to prove the validity of our theoretical results.

Main idea

- Aiming at the second-order MASs over a directed graph, based on the traditional sliding mode control (SMC) method, we propose a new adaptive discrete sliding mode controller that leads the followers to achieve finite-time tracking control of the single leader's position and velocity information in a discrete-time MAS.

- The existence and reachability of discrete sliding mode are discussed in our research. Using the method of finite-time stability by constructing a discrete Lyapunov function in a discrete system, it is demonstrated that the presented control algorithm can ensure the stability of the discrete MASs in finite time. Furthermore, the stability is not affected by variation of the discrete sampling time.

Main idea

- Compared with the existing discrete SMC method, the adaptive discrete sliding mode controller can adjust the time-varying parameter ε to decrease the inherent chattering of traditional SMC. Meanwhile, the speed at which the sliding mode switching surface is reached is not affected. Using the saturation function sat(·), and substituting the signum function sgn(·), which is widely used in the ideal SMC, the advantage of the proposed controller in our research is used to the greatest extent to create robustness and invariance to internal system perturbation and external disturbances.

Leader-follower discrete-time second-order MAS

- Leader dynamic model

$$\begin{cases} x_0(k+1) = x_0(k) + T_k v_0(k) \\ v_0(k+1) = v_0(k) \end{cases}$$

- Follower dynamic model

$$\begin{cases} x_i(k+1) = x_i(k) + T_k \cdot v_i(k) \\ v_i(k+1) = v_i(k) + T_k \cdot [u_i(k) + d_i(k)] \end{cases}$$

Finite-time consensus

- Finite-time consensus in discrete-time second-order MAS

$$\lim_{k \to T} |x_i(k) - x_0(k)| = 0$$
$$\lim_{k \to T} |v_i(k) - v_0(k)| = 0, \quad i \in 1, \ldots, n$$

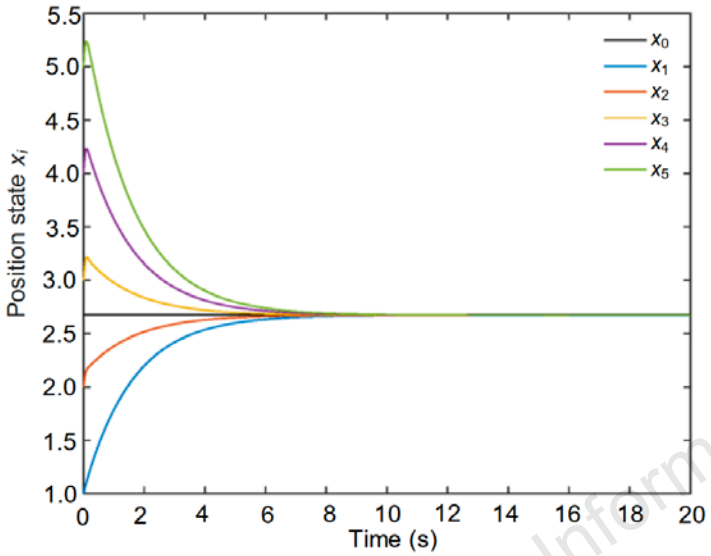
$$x_i(k) = x_0(k)$$
$$v_i(k) = v_0(k), \quad \forall k \geq T, \quad i \in 1, \ldots n$$

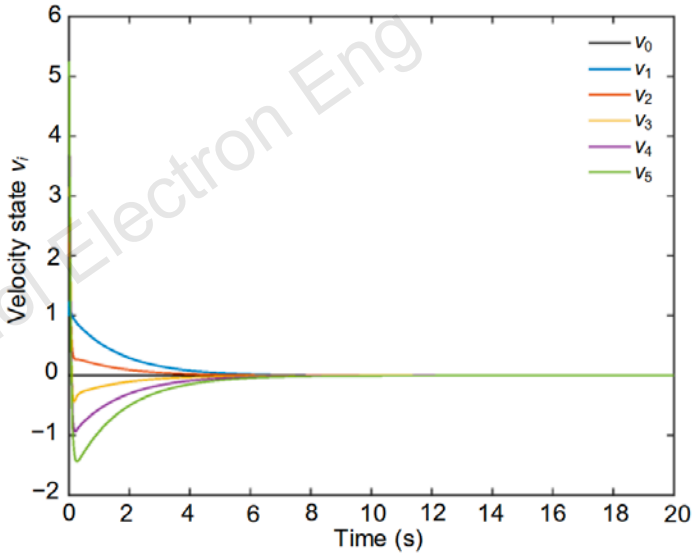
Control law

$$u_i(k) = \left[\tau\left(l_{ii} + b_i\right)\boldsymbol{C}_e\boldsymbol{B}\right]^{-1}\left\{\left[\varepsilon T M_i \operatorname{sat}\left(\boldsymbol{S}_i(k)\right)\right.\right.$$
$$\left.\left. + \left(qTM_i - \tau\right)\boldsymbol{S}_i(k)\right] - \tau\boldsymbol{C_e A e}\left(\boldsymbol{\xi}_i(k)\right) + \Phi\right\}$$

- The control law can make the MAS reach finite-time consensus.
- The control law can solve the SMC high-frequency chattering problem.

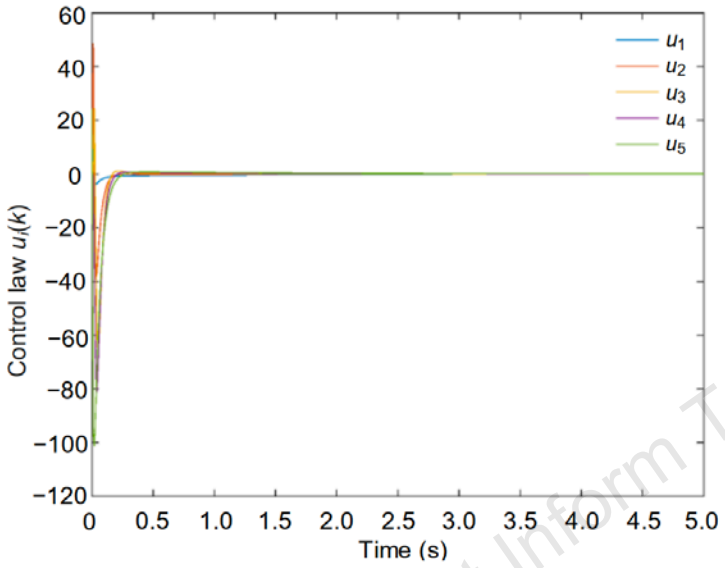
Simulation results

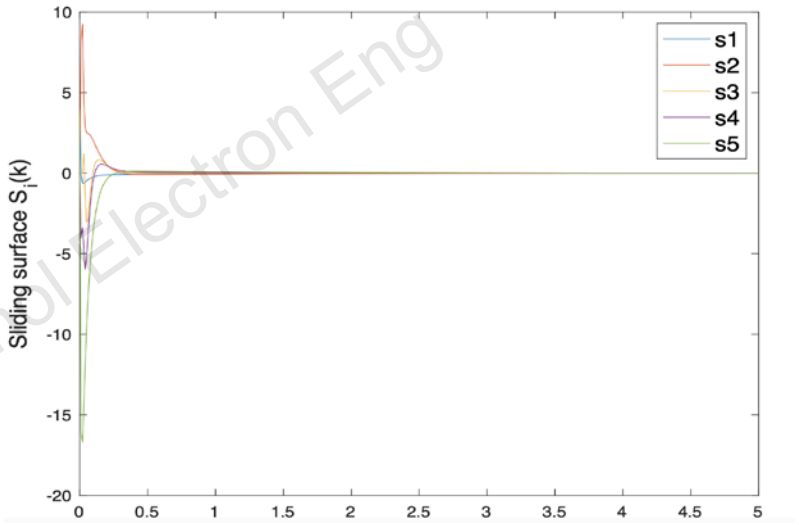




- The position and velocity state of finite-time leader-follower consensus with disturbances

Simulation results





- The control law and sliding surface state of finite-time leader-follower consensus with disturbances