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Finite-time consensus of second-order multi-agent systems via a structural approach

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Abstract

In this paper the finite-time consensus tracking problem for multi-agent systems with double-integrator dynamics is investigated under directed interaction topology by a structural approach. One continuous structural control strategy with only position measurements, which is based on estimated parameters and a finite-time separation principle, is proposed in order to solve the finite-time consensus tracking problem in a distributed way, i.e., by using the information of each agent's neighbors and itself, where control input of the leader, i.e., acceleration, is general instead of zero. Note that neither velocity measurements nor the acceleration of the leader is utilized by the structural control strategy, which provides a class of continuous control protocols for the finite-time consensus tracking problem. Furthermore, two specific control protocols are provided for directed and undirected topologies, respectively, which corroborate the feasibility of the structural control strategy. Finally, one numerical example is presented to demonstrate the efficiency of the theoretical results.

1. Introduction

A multi-agent system consists of a group of agents or nodes which communicate with each other locally by some designated link with some mission. Recently, it has attracted an increasing

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interest from a variety of fields including engineering, partly due to its broad applications in mobile robots and unmanned aerial vehicles, etc. The related topics to multi-agent systems include consensus [1–11], formation control [12,13], collective behavior of flocks and swarms [14–17], containment control [18], optimization-based cooperative control, etc. Among them, consensus is a paramount topic in which all agents communicate by local information with the purpose of reaching an agreement on certain quantities of interest by designing some appropriate control strategies or protocols.

There is a rich flow of research on consensus in the literature [1–10]. To quote a few, the consensus problem for agents with single-integrator dynamics was studied thoroughly in [1] under three cases: directed networks with fixed or switching topologies, and undirected networks with fixed topology and interaction time-delays, where two consensus strategies were provided. Besides single-integrator, the multi-agent systems with double-integrator dynamics have also been extensively researched in a large number of works. For instance, a connectivity-preserving consensus algorithm for second-order multi-agent systems was suggested with inherent nonlinear dynamics and a virtual leader in [4], and the consensus problem was solved asymptotically by the introduction of local adaptation strategies. For second-order multi-agent systems with nonidentical nonlinear dynamics, i.e., the inherent nonlinear dynamics of each agent being different, the distributed cooperative consensus tracking protocols were established with and without the velocity measurements, where bounded external disturbances were taken into consideration.

For consensus of multi-agent systems, convergence rate is of significance in practice which triggers a great deal of research on finite-time consensus, such as [19–41]. For example, finite-time consensus of multi-agent systems with single-integrator dynamics was extensively investigated with fixed topology, switching topology, undirected network, directed network, time-varying delays and nonlinear input protocol in [23,25,26]. The finite-time consensus problems for undirected networks with and without the leader were discussed in [27], where the distributed control protocols were presented for complete finite-time consensus in the absence of external disturbances and all agents moving into a bounded set in the presence of external disturbances. In [28], two bounded control protocols were provided for finite-time consensus of second-order multi-agent systems with one and multiple leaders and directed network. For finite-time consensus of second-order multi-agent systems without velocity measurements and input saturations, two observers of first-order and high-order were introduced to solve this problem in [29]. The robust finite-time consensus tracking problem for multirobot systems was discussed in [31]. Moreover, finite-time consensus problem for networked nonlinear mechanical systems with uncertainty and actuation failures was addressed under single-way directed interaction graph in [39].

This paper focuses on the finite-time consensus problem for double-integrator dynamical multi-agent systems with only position measurements under directed graphs. Based on estimated parameters and a finite-time separation principle, one structural control protocol is established to reach finite-time consensus without velocity measurements. After a finite time, the proposed control protocol will reduce to one with both position and velocity measurements since all the estimated parameters converge in finite time. Furthermore, it is well known that the asymptotic consensus problem for second-order agent systems has been widely studied with both position and velocity measurements and it is less challenging than that with only position measurements. Then, under the assumption of asymptotic consensus after some finite time, it is shown that the overall system can achieve finite-time consensus with only position measurements. The results here generalize a number of outcomes in the literature. For example, the multi-agent systems with single-integrator dynamics were studied in [23], whereas the second-order multi-agent systems are addressed here. The second-order finite-time consensus problem was investigated with both