Available online at www.sciencedirect.com

ScienceDirect

Journal of the Franklin Institute 351 (2014) 5399–5410

Journal of The Franklin Institute

www.elsevier.com/locate/jfranklin

Leader-following consensus of multi-agent systems with jointly connected topology using distributed adaptive protocols

Xiaowu Mu[a,*], Xia Xiao[a], Kai Liu[a,b], Jian Zhang[a]

[a]*School of Mathematics and Statistics, Zhengzhou University, Zhengzhou, Henan 450001, China*
[b]*College of Science, Henan Institute of Engineering, Zhengzhou, Henan 451191, China*

Received 30 June 2014; received in revised form 11 September 2014; accepted 30 September 2014
Available online 8 October 2014

Abstract

The leader-following consensus problems for multi-agent systems with a linear and Lipschitz nonlinear dynamics are considered. Distributed adaptive protocols and Lipschitz distributed adaptive protocols are respectively designed for the linear and Lipschitz nonlinear cases, under which leader-following consensus is reached for jointly connected topology. Finally, a simulation example is provided to illustrate the theoretical results.

1. Introduction

In recent years, coordination problem of multi-agent systems has received significant attention due to its broad applications in many areas including cooperative control of Sensor Networks [1], formation control [2], and traffic management [3].

A significant problem that appears frequently in the context of coordination of multi-agent systems is the consensus problem. Distributed strategies that achieve agreements have dramatic advances. Asynchronous asymptotic agreement problem for distributed decision-making systems considered in [4] is one of the pioneering works using distributed computation over networks.

*Corresponding author.
E-mail address: muxiaowu@zzu.edu.cn (X. Mu).

http://dx.doi.org/10.1016/j.jfranklin.2014.09.018
0016-0032/

The average-consensus control problem for networks of agents with first-order dynamics was considered under fixed and switching topologies in [5]. Distributed observers were designed for tracking control of multi-agent networks with an active leader in [6]. The consensus of linear multi-agent systems with switching directed topology by a new intermittent control was considered in [7]. The time-delay networked systems were discussed in [8,9]. The consensus problem of multi-agent systems was addressed in [10]. The distributed observer type protocols were given in [10], where there was a requirement that the smallest nonzero eigenvalue of the Laplacian matrix associated with the communication graph had to be known by each agent to determine the bound for the coupling weight. However, the smallest nonzero eigenvalue of the Laplacian matrix is global information. Therefore, the consensus protocols designed in [10] cannot be computed and implemented by the agents in a fully distributed fashion, i.e., using only the local information of its own and neighbors. To handle this problem, distributed adaptive static consensus protocols are proposed to adjust the coupling weights between neighboring agents in [11].

The effects of communication topology among the agents in the study of consensus problems are important, because it determines how the local behavior of each agent spreads throughout the group and has a strong impact on the stability of the multi-agent systems. When the interaction topology is time-varying, how to design control of multi-agent system is challenging. Under switching topologies, the consensus problem of multi-agent systems was discussed in [5,12–14]. The case of consensus with a leader which is also called distributed tracking or leader-following consensus is a particularly interesting topic, where the leader is a special agent whose motion is independent of all the other agents and thus is followed by all the other ones. A multi-agent leader-following problem with variable topology was considered in [15], where the state of the leader not only kept changing but also might not be measured. Wen [16] studied the distributed leader following consensus problem of linear multi-agent systems with switching directed topologies. Consensus tracking of nonlinear multi-agent systems with switching directed topology using M-matrix based approach was discussed in [17]. The leader-following consensus of non-linear multi-agent systems with jointly connected topology was considered in [18]. The leader-following consensus of multi-agent systems with adaptive dynamic protocol over switching communication topologies was mentioned in [19]. There are few results reported in the literature how to design distributed adaptive protocols to achieve the leader-following consensus with jointly connected topology. In this paper, we consider the leader-following consensus problem of the multi-agent systems with linear and nonlinear dynamics using linear and nonlinear distributed adaptive protocols under jointly connected topology. There are some main differences among this work and [11,19]. The consensus of multi-agent systems with fixed topology was studied in [11]. Li et al. [19] considered switching topologies, where the switching graphs were always connected in each switching interval. Here, only joint connectedness is assumed. Hence our restriction is more relaxed than the cases in [11,19]. In [11,19] leader-following consensus of linear systems was considered. In our case, linear and nonlinear systems are also considered.

The paper is organized as follows. In Section 2, some useful preliminary results are introduced and the problem formulation is presented. Section 3 contains the main results. Simulation results are presented in Section 4. The conclusion is given in Section 5.

Notations: Throughout this paper, the following notations are used. R^n denotes the n-dimensional Euclidean space; A^T stands for the transpose of the real matrix A; I_n represents an $n \times n$ identity matrix; $\mathbf{1}_n = (1, \ldots, 1)^T \in R^n$; $diag\{d_1, d_2, \ldots, d_n\}$ denotes a diagonal matrix with diagonal elements being $d_1, d_2, \ldots, d_n$; for real symmetric matrix P, $P > 0 (P \geq 0)$ means that matrix P is positive (semi-) definite; $A \otimes B$ denotes the Kronecker product of matrices A and B.