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Leader-following consensus of multi-agent systems with limited data rate

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Abstract

This paper investigates the leader-following consensus problem of time-invariant linear multi-agent systems with limited data rate. Based on the idea of assigning a priority level for each agent of the concerned multi-agent system, a novel distributed control law has been proposed. The proposed control law has two distinctive advantages. That is, it is fully distributed in the sense that it does not rely on the eigenvalues of the Laplace matrix associated with the topology. Moreover, the required data rate is independent of the number of agents and remains small even if the number of the agents in multi-agent systems is large. An example is finally given to illustrate the effectiveness of the proposed controller.

1. Introduction

Recently, the consensus problem of multi-agent systems has become a topic of wide interest [1–4], due to its broad applications in distributed sensor networks, formation control, coordination of mobile robots, etc. By exploiting the tool of matrix analysis [5–7], sliding mode [8,9] and backstepping [10,11], much progress has been made in studying the consensus problem of multi-agent systems.

In most early works on the consensus problem, the control law of each agent was designed based on the exact state information of itself and its neighborhood. However, implementation of such controllers is almost impossible in practice, due to the limited capacity of the

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communication channel between each pair of agents. In fact, the communication between each pair of agents in practice is often realized by the following three steps [12]: (i) the state information of the sender is encoded into a binary sequence; (ii) the binary sequence is transmitted by a channel; and (iii) the neighbor uses the encoded information to estimate the sender's state. By the above process, it is obvious that quantization cannot be neglected in communication of multi-agent systems.

Recently, quantized consensus problem of multi-agent systems has attracted great attention. Authors in [13,14] presented a logarithmic quantizer to solve the quantized consensus problem of single-integrator multi-agent systems. Since the quantizer is static, the required data rate for consensus of multi-agent systems cannot be limited. For the quantized consensus problem of single-integrator multi-agent systems, the authors in [15] proposed an effective dynamic quantization scheme so that multi-agent systems under an undirected graph can achieve average consensus with 3-bit quantizer information exchanging between each pair of agents at each time step. The authors in [16] extended the result of [15] to general linear multi-agent systems. It was shown that consensus can be achieved if the data rate is bigger than a certain integer, but the result might tend to be conservative [17]. The authors in [18] studied the quantized consensus problem for multi-agent systems with balanced communication topology while the authors in [19] considered the quantized consensus problem for multi-agent systems with directed switching topology. In all those mentioned works [13–19], discrete-time multi-agent systems were considered. For the consensus problem of continuous-time multi-agent systems, some results have been published recently [20,21].

This paper considers the quantized leader-following consensus problem for general linear discrete-time multi-agent systems. By introducing the concept of agents' priority level, a novel control law is proposed to solve the consensus problem of leader-following multi-agent systems with limited data rate. The main contributions of this work can be summarized as follows.

(1) Compared with most existing works on quantized consensus such as [13–15,18,19], a more general linear model of agents is considered. It is shown that the required data rate is independent of the number of agents and remains small even if the number of the agents in multi-agent systems is large.

(2) Compared to some existing works on quantized consensus such as [15,16], the design of the control law does not rely on the eigenvalue of the Laplace matrix associated with the topology, which is typically a global information. Thus the proposed control law is fully distributed.

The remainder of this paper is organized as follows. Section 2 gives some preliminaries and describes the leader-following consensus problem of general linear multi-agent systems with limited data rate. A distributed consensus protocol is presented in Section 3. Section 4 provides a numerical example to demonstrate the effectiveness of the proposed protocol, and Section 5 gives the final conclusion.

Notations: $\|.\|$ denotes the ∞-norm. $\rho(.)$ is the spectral radius. $|a|$ denotes the norm of $a \in \mathbb{C}$. $diag(A_1, A_2, \ldots, A_n)$ denotes a diagonal matrix. $\otimes$ is the Kronecker product with the following properties: 1) $(A \otimes B)(C \otimes D) = (AC \otimes BD)$; and 2) $(A \otimes B) \otimes C = A \otimes (B \otimes C)$.

2. Preliminaries

2.1. Communication graph

Communication between agents is described by a directed graph $\mathcal{G}(\mathcal{V}, \mathcal{E})$. Each agent is denoted as a node and $\mathcal{V} = \{0, 1, 2, \ldots, N\}$ is the set of nodes. $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$ is the set of directed edges, $(i,j) \in \mathcal{E}$ represents the communication from agent i to agent j. The out-degree of i