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ScienceDirect

Journal of the Franklin Institute 351 (2014) 1400–1418

Journal of The Franklin Institute

www.elsevier.com/locate/jfranklin

Output consensus of heterogeneous linear systems with quantized information

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Received 15 May 2013; received in revised form 29 August 2013; accepted 17 November 2013
Available online 26 November 2013

Abstract

In this paper, we design two distributed output consensus controllers for heterogeneous linear systems based on internal model principle and then study the quantization effect on the controllers when uniform quantizers are used in the communication channels. The first controller considers the general situation when the internal model state matrix of the system may be unstable and the communication graphs are strongly connected directed graphs. We prove that the bound of the consensus error is proportional to the quantizer parameter with a coefficient related to the size of the network and the property of the communication graphs. The second controller considers the situation when the internal model state matrix is neutrally stable and the communication graphs are undirected connected graphs. In this case, we derive a better bound of the consensus error which is proportional to the quantizer parameter and the coefficient is unrelated to the size of the network when the linear systems are homogeneous. Simulation examples are provided to illustrate the theoretical results.

1. Introduction

In recent years, the consensus and synchronization problems of multi-agent systems (MASs) have received intensive attention from various disciplines due to their broad applications in areas such as mobile sensor networks, vehicle formation control and satellite attitude alignment. In these problems, the main objective is to design a distributed control law for the agents to reach agreement on some variables of interest. Numerous results regarding different agent dynamics

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http://dx.doi.org/10.1016/j.jfranklin.2013.11.010

and different types of the communication graphs have been published on these topics and readers are referred to [1–9] and references therein for further details.

Most of the distributed control strategies in the literature require the agents to communicate with their neighbors and assume the availability of the exact information. However, this may be an unjustified simplification. Since the information is usually exchanged over digital communication channels, various restrictions need to be considered and quantization is one of the basic limitations induced by finite bandwidth channels. As a result, consensus problem under the quantization effect becomes interesting and meaningful. Most of the existing results on this topic focused on a variety of problems for discrete-time systems, including [10–16]. Quantization effects on continuous-time MAS attract attention more recently. The motivation for this approach mainly comes from a few considerations about the drawbacks of the sampled-data approach to the coordination problems of continuous-time networks. First, the sampled-data approach might require synchronous sampling and therefore accurate synchronization of all the agent clocks in the network which is difficult when the number of agents is large. Second, it might also require fast sampling rate which may not be feasible when the agents in the network only have limited computational ability. Finally, the sampled-data model may not fully preserve some of the features of the original model. Thus, it is important to directly tackle the continuous-time coordination problems with quantized information.

A few works have recently appeared on this class of problem. In [17], the authors considered the state agreement problem for first-order integrator systems with quantized relative information when the communication graphs are undirected trees. Distance-based formation control problem was also investigated. In [18], the authors studied the continuous-time average consensus problem for first-order integrator systems with uniformly quantized absolute information. Furthermore, a hysteretic quantizer was introduced to cope with the undesired chattering phenomena. In [19], asymmetrically and symmetrically quantized consensus protocols for first-order integrator systems were presented which guaranteed that the closed-loop system was Lyapunov stable and the agents converged to an appropriately defined set in finite time. Moreover, robustness of the symmetrically quantized consensus protocols to slowly varying communication errors was also analyzed. In [20], quantization effects on synchronization of mobile agents with second-order dynamics were investigated. Both the effects of logarithmic quantizers and uniform quantizers were studied. More recently, the work [21] studied the consensus problem of a network of first-order integrators with quantized absolute measurement and time-varying directed topology. In [22], a passivity based approach to collective coordination and synchronization problems for MAS in the presence of quantized relative measurements was investigated.

The existing results about the quantization effect on continuous-time consensus problem mostly dealt with agents with constrained dynamics such as homogeneous single or double integrators or agents that are passive under undirected communication graphs. To the authors' knowledge, corresponding results for general linear multi-agent systems under directed communication graphs have not appeared in the literature. It is worth pointing out that the analysis approach in the exiting literature for the undirected communication graphs cannot be directly generalized to cope with directed communication graphs. Furthermore, the agent dynamics are rarely exactly the same in practical multi-agent systems and the output consensus problem for heterogeneous linear systems is more challenging than the state or output consensus problems for homogeneous linear systems which can be seen as special cases of the former. Based on these observations, in this paper, we study the quantization effect on the output consensus problem for general heterogeneous linear systems under directed communication