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Journal of the Franklin Institute ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Journal of The Franklin Institute

Consensus of second-order multi-agent systems with random sampling via event-triggered control

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Received 13 March 2015; received in revised form 15 October 2015; accepted 3 January 2016

Abstract

In this paper, the consensus problem of second-order multi-agent systems is considered, where the data is sampled randomly and the topology has a directed spanning tree. An event-triggered control protocol based on the random sampling data and an improved time-dependent threshold is proposed for the consensus of second-order multi-agent systems, and thus the data transmission can be effectively reduced. Under some reasonable assumptions, the sufficient conditions are derived for assuring the second-order consensus based on the proposed event-triggered control protocol. Finally, some numerical examples are provided to demonstrate the effectiveness of the proposed event-triggered control protocol.

1. Introduction

In the past decade, the collective behaviors in autonomous agents are always a hot topic due to the fact that their broad applications in many areas, such as formation control [1–3], distributed optimization [4–6], flocking and swarming [7,8], unmanned air vehicles formations [9], information security [10,11], to name a few. One of the attractive collective behaviors is consensus, which refers to the problem that an agreement state can be reached as a result of local interactions (data transmissions) among multiple autonomous agents [12].

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http://dx.doi.org/10.1016/j.jfranklin.2016.01.014
0016-0032/

Please cite this article as: N. Mu, et al., Consensus of second-order multi-agent systems with random sampling via event-triggered control, Journal of the Franklin Institute. (2016), http://dx.doi.org/10.1016/j.jfranklin.2016.01.014

Since the pioneering papers [13–16], due to the superiority of reducing the data transmission, event-triggered control has attracted great attention from the researchers in the consensus of multi-agent systems. On the one hand, regarding to the first-order multi-agent systems, Dimarogonas et al. [17] and Hu et al. [18] proposed a decentralized event-triggered control protocol based on a state-dependent threshold, in which the data transmission only occurs when the measurement error exceeds the state-dependent threshold. Then Fan et al. [19] designed an event-triggered control protocol based on a combinational measurement error and further designed an iterative algorithm similar to self-trigger scheme for lowering the frequency of controller updates. Meanwhile, for excluding the Zeno-behavior, Meng et al. [20] and Guo et al. [21] formulated an event-triggered function with periodic sampling data. For avoiding the potential Zeno-behavior close to the consensus, Zhu et al. [22] and Mu et al. [23] introduced an improved event-triggered function for the multi-agent systems with continuous sampling data. Afterwards, Gao et al. [24] and Zhou et al. [25] considered the pinning controllability of complex networks with a distributed event-triggered control protocol and proved that the pinning controlled complex network can also assure the event-based consensus under some sufficient conditions. On the other hand, as to the second-order multi-agent systems, Yin et al. [26,27] and Syehoth et al. [28] proposed the event-triggered control protocols based on a state-dependent threshold and a time-dependent threshold, respectively. It is worth mentioning that the topology considered in [26,27] has a directed spanning tree and the topology considered in [28] is strongly connected or balanced directed.

However, reviewing the previous works, the following drawbacks are remained:

1. All of the existing works [17–28] assume that the sampling data is continuous or periodic. As a matter of fact, it is usually difficult to sample the data continuously or periodically in practical application, and thus a more practical event-triggered control protocol is attractive, in which only random sampling data is available.
2. For the second-order multi-agent systems, where the topology has a directed spanning tree, the effectiveness of the event-triggered control protocol proposed in [26,27] will decrease with the increasing number of agents. It is worth pointed out that when the number of agents is sufficiently large, the state-dependent threshold will be close to zero and numerous events will be triggered.
3. Although the time-dependent threshold proposed in [28] can address the drawback of the state-dependent threshold, but the topology of the multi-agent systems considered in [28] is required to be strongly connected or balanced directed. It is well known that the topology having a directed spanning tree is more general than the strongly connected topology and the balanced directed topology.

Motivated by the above discussions, the consensus problem of second-order multi-agent systems is considered in this paper, where the data is sampled randomly and the topology has a directed spanning tree. A more practical event-triggered control protocol based on the random sampling data is proposed, in which the event-triggered function is designed with an improved time-depended threshold. Compared with the existing event-triggered control protocols for the consensus of second-order multi-agent systems [26–28], this proposal can obtain three advantages:

1. The proposed protocol is based on random sampling data, which is more practical than the continuous sampling data employed in [26–28]. In addition, the proposed protocol can naturally exclude the Zeno-behavior by the positive sampling instants.

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