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Journal of The Franklin Institute

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On designing decentralized impulsive controllers for synchronization of complex dynamical networks with nonidentical nodes and coupling delays☆

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Received 5 November 2013; received in revised form 23 April 2014; accepted 25 April 2014

Abstract

This paper investigates the problem of designing decentralized impulsive controllers for synchronization of a class of complex dynamical networks (CDNs) about some prescribed goal function. The CDNs are allowed to possess nonidentical nodes and coupling delays. Two cases of time-varying coupling delays are considered: the case where the coupling delays are uniformly bounded, and the case where the derivatives of the coupling delays are not greater than 1. The synchronization analysis for the first case is performed by applying a time-varying Lyapunov function based method combined with Razumikhin-type technique, while the synchronization analysis for the second case is conducted based on a time-varying Lyapunov functional based method. For each case, by utilizing a convex combination technique, the resulting synchronization criterion is formulated as the feasibility problem of a set of linear matrix inequalities (LMIs). Then, sufficient conditions on the existence of a decentralized impulsive controller are presented by employing these newly obtained synchronization criteria. The local impulse gain matrices can be designed by solving a set of LMIs. Finally, two representative examples are given to illustrate the correctness of the theoretical results.

☆This work was supported by the National Natural Science Foundation of China under Grant 61164016 and Guangxi Natural Science Foundation (2011GXNSFA018141 and 2013GXNSFDA019003) and an Innovation Project of Guangxi Graduate Education (YCSZ2014036).

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http://dx.doi.org/10.1016/j.jfranklin.2014.04.014

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1. Introduction

Complex dynamical networks (CDNs) are demonstrated to be ubiquitous in real world [1–3]. In general, a complex dynamical network consists of a large number of nodes connected by the links that display complex topological properties. Typical examples of CDNs include internet networks, electricity distribution networks, biological networks, and epidemic spreading networks. The broad applications of CDNs have triggered a series of important research on collective behavior of CDNs. As the major collective behavior, synchronization of CDNs which is exhibited in many physical and biological systems has received a great deal of attentions within science and technology communities. Many criteria for local and global synchronization of CDNs have been proposed [4–11]. In the case where the CDN cannot reach synchronization by itself or we want the CDN to synchronize to some desired state, certain control laws should be designed such that the controlled CDNs achieve synchronization. During the past few decades, various control strategies for synchronization of CDNs have been developed, e.g. adaptive control [12–14], pining control [15–17], observer-based control [18,19], backstepping design [20,21], etc.

With the rapid development of digital sensors and controllers, the digital control technology gradually substitutes the analog control technology in control engineering field. In the background of digital control technology, although the CDN itself is a continuous-time system, the state information is only available at discrete sampling times. Therefore, it is of importance to investigate the synchronization problem of CDNs by using sampled information. The control strategies for synchronization of CDNs via sampled information can be classified into two classes: sampled-data control and impulsive control. In the frame of sampled-data control, via a zero-order holder, the states of the nodes are adjusted continuously by the sampled information. In the frame of impulsive control, the states of the nodes are only adjusted according to the sampled information at the discrete-time instants. Thus, the impulsive controller has more simple structure than the sampled-data controller. It is worth mentioning that a distinct feature of impulsive control is that it allows us to synchronize the CDNs only by using the impulses sampled from the nodes at discrete time instants. So, compared with the continuous-time control strategies, the impulsive control strategy can effectively save bandwidth and reduce communication cost.

The synchronization issue of CDNs using sampled-data controllers has been investigated in [22–24]. In [25], the consensus problem of directed networks of multiple agents with nonlinear dynamics and sampled-data information has been studied by using a delayed-input approach. Recently, the impulsive synchronization problem of CDNs has been investigated in [26–32], and several synchronization criteria are established for different kinds of CDNs. In [26], an impulsive synchronization scheme for a class of uncertain CDNs was proposed, and some criteria for local and global robust synchronization were derived. In [27], the distributed impulsive synchronization problem for the CDNs with state delays and coupling delays was studied, and a distributed impulsive control strategy was proposed to achieve global synchronization of the considered CDNs. By applying an impulsive delay differential inequality, some simple sufficient conditions for global synchronization of delayed CDNs were presented in [28]. The issue of pinning synchronization for a class of delayed CDNs via a single impulsive controller was investigated in [29], and some sufficient conditions for pinning synchronization were provided therein. The output synchronization problem of a class of impulsive complex dynamical networks with time-varying delay was studied in [30], some criteria for local and global exponential output synchronization were obtained by using the Lyapunov functional method. In [31], a hybrid impulsive control strategy was proposed to synchronize the given CDN with nonidentical nodes to a desired goal trajectory, and some synchronization criteria were derived by utilizing the Lyapunov function and the Lyapunov

Please cite this article as: W.-H. Chen, et al., On designing decentralized impulsive controllers for synchronization of complex dynamical networks with nonidentical nodes and coupling delays, Journal of the Franklin Institute. (2014), http://dx.doi.org/10.1016/j.jfranklin.2014.04.014