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Education Article

Synchronization of dynamical networks with nonlinearly coupling function under hybrid pinning impulsive controllers

Yuanyuan Li[a], Jungang Lou[b], Zhen Wang[c,*], Fuad E. Alsaadi[d]

[a] *Department of Applied Mathematics, Nanjing Forestry University, Nanjing 210037, PR China*
[b] *School of Information Engineering, Huzhou University, Huzhou 313000, China*
[c] *College of Mathematics and Systems Science, Shandong University of Science and Technology, Qingdao 266590, China*
[d] *Department of Electrical and Computer Engineering, Faculty of Engineering, King Abdulaziz University, Jeddah 21589, Saudi Arabia*

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Abstract

In this paper, the globally exponential synchronization problem of dynamical networks with nonlinearly coupling function is considered. Hybrid pinning control strategies are established to force the states of the network to follow some objective trajectory. The impulsive pinning controllers are used to control a fringe of nodes at the impulsive instants, while during the impulsive instants, pinning state-feedback controllers are designed to achieve the control objective. Finally, the validity of the developed techniques is evidenced by an illustrative example.

1. Introduction

The synchronization of dynamical networks has been obtained extensive attention recently, partly because it plays a significant part in many different circumstances including engineering,

* Corresponding author.
E-mail address: wangzhen_sd@126.com (Z. Wang).

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ecology and biology [1]. The goal of the synchronization in networks is to drive the coupled systems to a common state or a common trajectory by utilizing local information exchange among the nodes [2–4]. The synchronization problem of dynamical networks has attracted much attention [2,5–8]. In [5], it was shown that many coupled oscillator array configurations can be unified as a simple form and hence a master stability function can be employed to decide the stability of the synchronous state in networks. Similar with the concept of synchronization, many results have also been paid to the problems of state estimation [9], flocking [10] and swarming [11].

Recently, some interesting results have been obtained concerning the synchronization, state estimation and some other dynamical behaviors of networks with some special features or communication constraints [12], including time delay [13,14], noises [15], quantization [16] and so on. In [17], via only controlling partial states, Li obtained some synchronization criteria for the stochastic neural networks. The synchronization of network is realized by the interconnected coupling among the nodes, the final synchronized state in the network is difficult to control or compute because of the complex dynamical behavior of the single node. Hence, it is now an interesting and challenging issue to compel the whole networks to the desired state or trajectory [18]. For dynamical networks with chaotic nodes, since chaotic systems defy synchronization, there is also a strong requirement to design efficient controllers to synchronize networked coupled chaotic systems. Hence, this paper will propose efficient controllers to compel the dynamical network to certain desired trajectory.

Normally, complex dynamical networks include huge amounts of individual nodes, and hence it would be very costly and complicated to control all of the nodes [19–21]. In [22], Li et al. proposed the pinning controller for linear coupled dynamical networks and showed that the whole network can be well compelled to certain desired state via only controlling partial nodes. In [21], Liu et al. exploited a general theory to explore the controllability of arbitrary network, and used these analytical tools to a few real networks and find out that the networks' degree distribution decides the amount of driver nodes. The idea of pinning control has been widely used to control different kinds of networks [23–25]. Following this idea, many efficient control strategies have been designed to control dynamical network, such as pinning state-feedback control strategy [26,27], pinning impulsive strategy [28]. Impulsive effects mean that the states of systems are subject to abrupt change at certain instants [29–31]. Impulsive effects widely exist in biological systems and networks [32–36]. In [37], Yang *et al.* designed a non-chattering control to investigate the fixed-time synchronization for impulsive dynamical networks.

Inspired by the aforementioned arguments, this paper will discuss the pinning control of dynamical networks with nonlinear couple function. In [18], Lu et al. offered a single impulsive controller for the synchronization of impulsively coupled networks, which is demonstrated to be effective to improve the convergent rate of the synchronization process. Different from Lu et al. [18], dynamical networks with nonlinear coupling and without impulsive coupling will be studied in this paper. We will design effective hybrid pinning controllers including pinning state-feedback controllers (PSCs) and pinning impulsive controllers (PICs) to guide the whole network to certain trajectory here. The effects of PSCs and PICs will be presented in the derived criteria, respectively. The effectiveness of our derived analytical results will be prove by a numerical example.

Notations: $\mathbb{R}^+ = [0, +\infty)$, $\mathbb{N} = \{1, 2, 3, \ldots\}$. Let $\mathbb{R}$, $\mathbb{R}^{n\times n}$ and I_n denote the real numbers set, $n \times n$ real matrices and the identity matrix of order n, respectively. $Q > 0$ and $\lambda_{\max}(Q)$