Chaos, Solitons and Fractals 86 (2016) 82–91

Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

Nonlinear Science, and Nonequilibrium and Complex Phenomena

journal homepage: www.elsevier.com/locate/chaos

Cluster synchronization in community network with hybrid coupling

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ARTICLE INFO

Article history:
Received 30 August 2015
Revised 26 January 2016
Accepted 15 February 2016
Available online 14 March 2016

Keywords:
Hybrid coupling
Community network
Cluster synchronization
Adaptive control

ABSTRACT

A general model of community network with hybrid coupling is proposed in this paper. In the community network model with hybrid coupling, the inner connections are in the same type of coupling within the same community and in different types of coupling in different communities. The connections between different pair of communities are also nonidentical. Cluster synchronization of community network with hybrid coupling is investigated via adaptive couplings control scheme. Effective controllers are designed for constructing an effective control scheme and adjusting automatically the adaptive external coupling strength by taking external coupling strength as adaptive variables on a small fraction of network edges. Moreover, the impact of the topology on the synchronizability of community network is investigated. The numerical results reveal that the number of links between communities and the degree of the connector nodes have significant effects on the synchronization performance.

1. Introduction

Network synchronization can be observed in a wide range of application domains, including sociology, and technology [1–3]. Synchronization of coupled dynamical systems has been the subject of much considerable research efforts in the past two decades [4,5]. Complete synchronization of coupled chaotic units has been extensively studied [6–8]. Besides the well known complete synchronization, many different synchronization phenomena, such as explosive synchronization [9,10], impulsive synchronization [11], cluster synchronization [12–14], etc., have been studied during the last several decades. Cluster synchronization, as a particular type of collective behavior, implies that the oscillators split into several clusters, such that the oscillators synchronize with one another only in the same cluster, but no synchronization occurs among the different clusters. Cluster synchronization has attracted increasing attention due to wide observation of the phenomena in many fields of science [15]. One of the most outstanding problems is how to achieve a desired cluster synchronization pattern by designing suitable coupling control scheme. By choosing different coupling technique, the stability of selected cluster synchronization in coupled Josephson equations was investigated. The authors recognized that the stability of cluster synchronization depends on the selection of the coupling schemes. Ma et al. [16] investigated a coupling scheme with cooperative and competitive weight-coupling to realize cluster synchronization for the connected chaotic networks. Meanwhile, many control approaches have been developed to synchronize complex networks, such as feedback control [17,18] and adaptive control [19], pinning control [20] and so on.

Actually there are two main factors contributing to the network synchronization. One is the isolated node

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http://dx.doi.org/10.1016/j.chaos.2016.02.022
0960-0779/

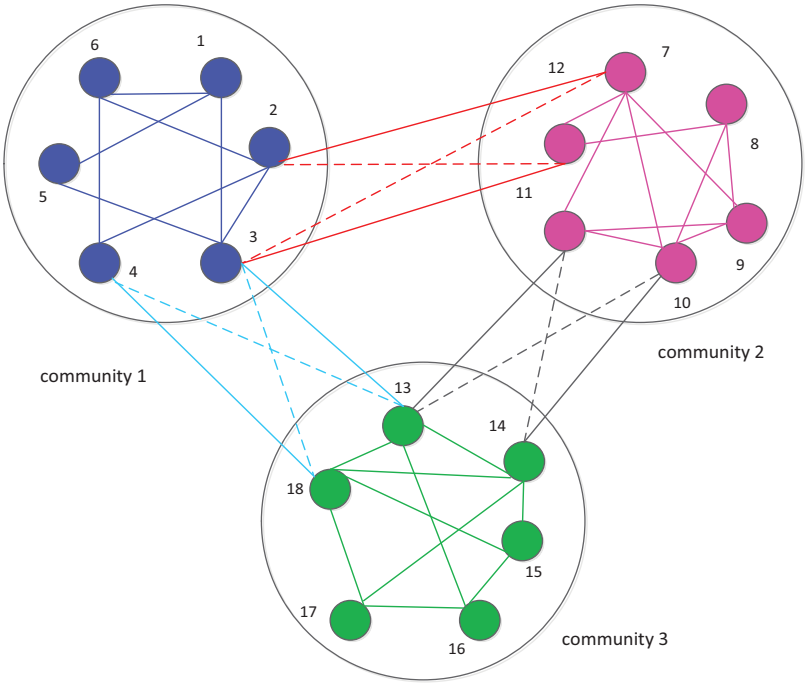

Fig. 1. The community network with hybrid coupling, where different colored nodes denote that they have different dynamics and edges with different color represent different interaction.

dynamics, and the other is the topology of the complicated network. Recently, many large-scale real systems have been found that they have community structure, such as social and biological networks [21], school friendship networks [22], and so on [23,24]. In this sense, community networks can describe the real world better. Generally, the links of the nodes may have higher density if they belong to the same community and lower density if they belong to different communities. On the other hand, the interactions between nodes in the same community are usually identical and those in different communities are non-identical. Moreover, the interactions between the same pair of communities may be identical and those between different pair of communities may be different. That is to say, there exist diverse coupling forms in community network. For better describing this kind of phenomena, community network model with hybrid coupling is introduced. The schematic diagrams of the community network with hybrid coupling structure are shown in Fig. 1.

However, most of the previous results, have been devoted to the cluster synchronization of community networks [25,26]. But few works on the cluster synchronization of the network with community structure where the individual units are allowed to interact through different types of coupling in different communities and the connections between different communities are also different. We will focus on the cluster synchronization in community networks with hybrid coupling, whose connections that correspond to the same type of coupling within the same community and different types of coupling between different communities. The local dynamics of nodes in one community will be the same and those in different communities can be either same or different.

As we know, the coupling strength plays a key role in achieving synchronization. In [27], Zhou and Kurths study the synchronization problem in complex networks with dynamical weights and find that dynamical weights can enhance synchronization. DeLellis et al. investigated two local adaptive strategies for the synchronization of complex networks. By tuning all the coupling weights of dynamical networks, the synchronization can be easily achieved. However, for large-scale dynamical networks, they usually contain a large number of edges, tuning all the coupling weights are impractical [28]. Inspired by pinning control scheme, the synchronization is realized through tuning only the coupling strength between different communities. This method decreases the control cost to some extent by reducing the number of controlled coupling weights.

This paper investigates the cluster synchronization in network with community structure by adaptive control method. In Section 2 the community network model with hybrid coupling and some preliminaries are introduced, in Section 3, the cluster synchronization of community network with hybrid structure is investigated by adaptive feedback control and adaptive coupling strength control. In Section 4, examples of numerical simulations are presented to show the validity of the proposed approach. Finally, discussions on the topology of network structure and the degree of connector nodes on the performance of synchronization and the conclusions of this work are given in Section 5.