Physica A 509 (2018) 111–120

Contents lists available at ScienceDirect

Physica A

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

Finite-time event-triggered synchronization for reaction–diffusion complex networks

Aijuan Wang [a,b], Xiaofeng Liao [a,b,*], Tao Dong [a]

[a] College of Electronic and Information Engineering, Southwest University, Chongqing 400715, China
[b] Chongqing Key Laboratory of Nonlinear Circuits and Intelligent Information Processing, China

HIGHLIGHTS

- The model of CNs considered in this paper, is a temporal–spatial system due to the reaction–diffusion term.
- A new nonlinear ETC based on the sampling data is proposed. The proposed ETC can achieve FTS and exclude Zeno behavior naturally. The exclusion of Zeno behavior is a considerable challenge for the general ETC due to the existence of the reaction–diffusion term.
- Some sufficient conditions of the synchronization for the RDCNs are obtained. The finite time of the synchronization is definitely estimated.

ARTICLE INFO

Article history:
Received 5 February 2018
Received in revised form 18 April 2018
Available online xxxx

Keywords:
Reaction–diffusion complex networks (RDCNs)
Finite-time synchronization
Event-triggered control
Sampled-data
Zeno behavior

ABSTRACT

In this paper, we investigate the finite-time event-triggered synchronization problem of the reaction–diffusion complex networks (RDCNs) with Dirichlet boundary conditions. A novel nonlinear event-triggered controller is developed, which is based on the random sampled-data. Under the proposed controller, it is found that the Zeno behavior is naturally excluded and the finite-time synchronization of RDCNs is guaranteed. Moreover, by utilizing Lyapunov functional method and the inequality techniques, the finite-time synchronization condition of the RDCNs is derived as well as the finite time is calculated. Finally, numerical simulation results are provided to demonstrate the theoretical results.

1. Introduction

Recently, complex networks (CNs) have been one of the focal points from many researchers due to their extensively real applications in different engineering areas, such as biological systems, neural networks (NNs), sensor networks and robotic teams and so on [1–6]. Particularly, synchronization problem, as a typical dynamics behavior of CNs, has been widely investigated [7–13], where all sorts of CNs are considered. For example, the synchronization for CNs with time-varying delay [10,13] and CNs with switching disconnected topology [12] are studied.

In the recent literature, there is an increasing interest in CNs with the reaction–diffusion behavior because of their true existence in many real systems such as predator–prey system, neural network, cellular network and so on [14–19]. The reaction–diffusion behavior makes the dynamic behaviors of CNs more complicated. Hence, the effect of reaction–diffusion on synchronization problem for CNs should be paid attention. Up till the present moment, there are many studies on synchronization problem of the different types of RDCNs [20–25]. The synchronization problem for the coupled RDCNs

* Corresponding author at: College of Electronic and Information Engineering, Southwest University, Chongqing 400715, China.
E-mail address: xfliao@swu.edu.cn (X. Liao).

https://doi.org/10.1016/j.physa.2018.05.144
0378-4371/

[20,21] and RDCNs with time-varying delays [22,23] are considered. In [24,25], the authors investigate the synchronization problem of RDCNs via intermittent control strategy. It should be noted that the synchronization for the RDCNs in [20–25] is asymptotic. In reality, however, achieving the synchronization is always expected in a finite time, which is called finite-time synchronization. In recent years, researchers are paying attention to the finite-time synchronization for the different CNs [26–30]. To the best knowledge of the authors, there are few literatures on the finite-time synchronization for the RDCNs. In [20–25], the synchronization of the RDCNs is investigated instead of the finite-time synchronization of RDCNs. Besides, the finite-time synchronization for the different CNs rather than RDCNs is discussed in [26–30]. Based on these observations, in this paper, we aim to investigate the finite-time synchronization problem of the RDCNs.

On the other hand, the control strategies employed in the above mentioned articles [25–30] are continuous time, just periodically intermittent control or impulsive control, which are independent of dynamic behavior. In this case, controller updates are at fixed times so that a small change of nodes' states in a long enough time interval can cause unnecessary updates of controller, which results in the network congestion and communication load. As an alternative, the event-triggered control (ETC) is a successful strategy for conquering the defects of the continuous control strategy and reducing the communication between nodes. Up to date, the different types of ETC strategies are proposed to tackle the synchronization problem of CNs [31–34]. In [31,32], the authors investigate the synchronization problem of CNs via event-triggered scheme. The event-triggered synchronization for CNs with Markovian switching topologies is discussed [33,34]. Following them, the authors of this paper study the synchronization of RDCNs by designing the event-triggered controller based on sampling data in [35]. However, the controller proposed in [35] fails to address the finite-time synchronization problem of RDCNs. The observation inspires us to develop a new event-triggered controller to tackle the finite-time synchronization problem of RDCNs.

Motivated by the above discussions, in this paper, we investigate the finite-time synchronization problem of RDCNS with Dirichlet boundary conditions via ETC. Contributions of this paper includes three parts, which are as follows:

(1) The model of CNs considered in this paper, is a temporal–spatial system due to the reaction–diffusion term.

(2) A new nonlinear ETC based on the sampling data is proposed. The proposed ETC can achieve finite-time synchronization and exclude Zeno behavior naturally. The exclusion of Zeno behavior is a considerable challenge for the general ETC due to the existence of the reaction–diffusion term.

(3) Some sufficient conditions of the synchronization for the RDCNs are obtained. The finite time of the synchronization is definitely estimated.

The remainder of this thesis is organized as follows. Graph theory, ECT strategy and model description are presented in Section 2. The finite-time synchronization analysis is shown in Section 3. Simulation verification is given in Section 4. Conclusion is finally drawn in Section 5.

Notations: $R^{m\times n}$ denotes the set of $m\times n$ dimensional real matrices. R is the set of real numbers. For a given vector or matrix X, X^T denotes its transpose. $I_N = diag\{1, 1, \ldots, 1\}_{N\times N}$. $|\cdot|$ denotes the Euclidean norm. For the given $\alpha \in R$ and $x \in R$, we define $sig(x)^{\alpha} \le sign(x)\,|x|^{\alpha}$. $\mathbf{1} = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}_{N\times 1}$.

2. Problem statement

2.1. Graph theory

In this section, some concepts and graph theory are given. Let $G = (\nu, \varepsilon, A)$ be a weighted undirected and connected graph, where $\nu = \{1, 2, \ldots, N\}$ is a set of vertices and $\varepsilon \subseteq \nu \times \nu$ is a set of edge. $(i, j) \in \varepsilon$ is an edge which presents the communication links between node i and node j. $N_i = \{j \in \nu | (j, i) \in \varepsilon\}$ is a set of neighbors of node i and $j \ne i$. $A = (a_{ij})_{N\times N}$ with $a_{ii} = 0$, $a_{ij} > 0 \Leftrightarrow j \in N_i$ is the connection adjacency matrix of the graph G. If every node in G is connected to other any node, G is called connected. $\deg in\,(i) = \sum_{j=1}^{N} a_{ij}$ is the degree of node i. $L = D - A$ is the Laplacian matrix of G, where $D = diag\,(\deg in\,(1), \ldots, \deg in\,(N))$. The matrix L is the symmetric and positive semi-definite. For a connected graph G, L satisfies $\mathbf{1}^T L = 0$. $\Omega = \left\{x = \left(x_1, \ldots, x_q\right)^T | |x_k| < l_k, k = 1, \ldots, q\right\}$ is an open bounded domain in R^q with smooth boundary $\partial\Omega$.

2.2. Model description

The model of the RDCNs considered in this paper is as follows:

$$\frac{\partial z_i(x,t)}{\partial t} = K\Delta z_i(x,t) + Bf\left(z_i(x,t)\right) + cu_i(x,t)\,,\ \ i = 1,\ 2,\ \ldots,\ N, \tag{1}$$

with the initial value and Dirichlet boundary conditions

$$\begin{aligned} &z_i(x,0) = \varphi_i(x)\,, x \in \Omega, \\ &z_i(x,t) = 0, (x,t) \in \partial\Omega \times [0, +\infty)\,, \end{aligned} \tag{2}$$