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Event-triggered communication for synchronization of Markovian jump delayed complex networks with partially unknown transition rates

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ABSTRACT

In this paper, exponential synchronization problems are investigated for an array of Markovian jump delayed complex networks with partially unknown transition rates and discontinuous diffusions. To impel the array complex networks to achieve exponential synchronization, a new randomly occurring event-triggered control strategy is proposed. The idea of event-triggered control strategy is that the coupling term and controller update data only at the event-triggered instants, which can reduce the communication load and energy consumption. By constructing a novel stochastic Lyapunov–Krasovskii function, some exponential synchronization criteria are obtained in terms of LMIs and famous Halanay inequality. Furthermore, we obtain a positive lower bound of the event intervals which can exclude the Zeno behaviors. Finally, a simulation example is given to illustrate the effectiveness of the theoretical results.

1. Introduction

Complex networks widely exist in the real world, such as the world wide web, social systems, food webs, power grids and the Internet [1–4]. Synchronization problems of complex networks have been investigated extensively and a host of corresponding profound results have been established based on all kinds of methods(see [5–11] and references therein).

In many practical complex networks, delay is inevitable owing to the finite speed of signal transmission and information processing, which may reduce the performance and stability of the network. So synchronization issues of the delayed networks have attracted increasingly attention and many results have been proposed on this topic(see [12–16] and references therein). On the other hand, it is noted that the coupling structures of the complex networks may be subject to random abrupt variation main due to sudden environmental changes, random component repairs or failures, and changing in subsystem interconnections. A suitable mathematical pattern is employed to represent the switch of the structure by introducing a continuous time Markov chain(see [17–20]). However, almost all of these results are built upon the assumption that the transition rates of the Markov chain are completely accessible. In fact, it is difficult to obtain all the elements of the transition rate matrix. Some researchers have paid attention to the case of uncertain transition rates [21–23]. Unfortunately, such uncertainties have to require the knowledge of bound or structure of uncertainties, which is conservative to a certain

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extent. Therefore, it is necessary and significant to research on more general Markovian switching systems with partially unknown transition rates. Recently, authors in [24,25] investigated the problems of stabilization for a class of Markovian jump linear systems with partly unknown transition rates. Cui et al. [26] discussed the finite-time synchronization for Markovian jump complex networks with partially unknown transition rates. To the best of our knowledge, the exponential synchronization problems of Markovian switching delayed complex networks with partly unknown transition rates have seldom been investigated and remain challenging, which is the first motivation of this paper.

Usually, there exist some network systems which cannot achieve synchronization by themselves. So a variety of control methods are proposed to impel the networks to achieve synchronization, such as global control, intermittent control, impulsive control and so on(see [13,14,26–31] and references therein). However, the traditional control strategies update data continuously or at a fixed sampling rate, which lead to unnecessary bandwidth and energy consumption. In order to reduce the energy consumption and traffic, event-triggered control is an excellent alternative(see [18,32–38]), which can decrease the controller actuations and the communication between the nodes. The idea of this strategy is that the sampling action are carried out only at event-triggered instants, which guarantees that only really necessary state signals will be sent out to neighbor nodes and controller. These event-triggered instants are determined by predefined event-triggered function. Compared with traditional control strategies, the event-triggered control strategy is more applicable for the network systems with limited resources.

Åström and Bernhardsson in [32] pointed out that the event-based sampling technique showed better performance than sampling periodically in time for some simple systems. Lang et al. in [33] applied event-triggered strategies to actuate synchronization for delayed neural networks. Chen et al. in [34] deduced synchronization conditions of linearly coupled networks based on event-triggered communication. However, the coupling structure in literatures [33,34] are fixed, which is conservative to some extent. Authors in [18,36] considered the synchronization for networks with Markovian switching topology via event-triggered communication strategy, yet they have not considered the case of partly unknown transition rates. Furthermore, the controlled plants may be subject to random failures, sudden environmental changes, packet dropouts [39] and so on. So randomly occurring control strategy is more realistic. To the best of our knowledge, few papers consider the randomly occurring event-triggered control strategy, let alone applying this method to study the synchronization issues of Markovian jump delayed complex networks with partly unknown transition rates, which is the second motivation of this paper.

The main aim of this paper is to identify the synchronization conditions and estimate the positive lower bound of the event intervals. The main highlights of this paper are summarized as follows: (1) The network model in this paper involves time delay and partly unknown transition rates, which is more practical than the models in [18,34,35,38]. (2) Different from the most existing results with partly unknown transition rates [24–26], the synchronization trajectory in this paper is dynamic, which will be adjusted according to the states of nodes. (3) A randomly occurring event-triggered control strategy is proposed to study the synchronization issue of Markovian jump delayed complex networks with partly unknown transition rates. (4) The positive lower bound of the event intervals is obtained which can exclude undesired accumulation of event instants(Zeno behaviors).

The rest of this paper is organized as follows. Section 2 proposes a new array of complex networks with delay, discontinuous diffusions and Markovian switching of which transition rates are partially unknown, and outlines some necessary definitions, assumptions and lemmas. In Section 3, by constructing a novel stochastic Lyapunov–Krasovskii function, several exponential synchronization criteria are established in terms of LMIs and famous Halanay inequality, and a positive lower bound of the event intervals is given. A numerical simulation is introduced in Section 4 to show the effectiveness of theoretical results. Finally the conclusions are drawn in Section 5.

Notations: Throughout this paper, I_n is an identified matrix with dimension n, 0 is a zero matrix with appropriate dimensions. If all eigenvalues of a matrix $A \in \mathbb{R}^{n\times n}$ are real number, we sort them as $\lambda_1(A) \le \lambda_2(A) \le \cdots \le \lambda_n(A)$. For a vector $\boldsymbol{x}$, let $\boldsymbol{x}^\top$ denote the transpose vector and $\|\boldsymbol{x}\|$ denote L_2-vector norm. $\boldsymbol{1}_n$ is a n-dimension vector which all the elements equal 1. U is a matrix in which all the elements equal $\frac{1}{N}$. $\mathbb{E}$ stands for the mathematical expectation. The symbol $\otimes$ denotes the Kronecker product.

2. Preliminaries

Let $\{\sigma_t,\ t \ge 0\}$ be a right-continuous and time-homogeneous Markov chain on the probability space taking values in a finite state space $S = \{1, 2, \ldots, m\}$ with generator $Q = (q_{ij})_{m\times m}$ given by

$$P\{\sigma_{t+\Delta t} = j|\sigma_t = i\} = \begin{cases} q_{ij}\Delta t + o(\Delta t), & i \ne j, \\ 1 + q_{ii}\Delta t + o(\Delta t), & i = j, \end{cases} \tag{1}$$

where $\Delta t > 0$ and $\lim_{\Delta t\to 0} o(\Delta t)/\Delta t = 0$, $q_{ij} \ge 0 (i \ne j)$ is the transition rate from the state i to the state j, $q_{ii} = -\sum_{j=1, j\ne i}^{m} q_{ij}$.

In this paper, the transition rates of the Markov chain are assumed to partly accessible, and the transition rate matrix is descried as follows