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Impulsive synchronization of Markovian jumping randomly coupled neural networks with partly unknown transition probabilities via multiple integral approach

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ABSTRACT

This paper studies the impulsive synchronization of Markovian jumping randomly coupled neural networks with partly unknown transition probabilities via multiple integral approach. The array of neural networks are coupled in a random fashion which is governed by Bernoulli random variable. The aim of this paper is to obtain the synchronization criteria, which is suitable for both exactly known and partly unknown transition probabilities such that the coupled neural network is synchronized with mixed time-delay. The considered impulsive effects can be synchronized at partly unknown transition probabilities. Besides, a multiple integral approach is also proposed to strengthen the Markovian jumping randomly coupled neural networks with partly unknown transition probabilities. By making use of Kronecker product and some useful integral inequalities, a novel Lyapunov–Krasovskii functional was designed for handling the coupled neural network with mixed delay and then impulsive synchronization criteria are solvable in a set of linear matrix inequalities. Finally, numerical examples are presented to illustrate the effectiveness and advantages of the theoretical results.

1. Introduction

A complex dynamical network consists of a large set of nodes sprouting according to their respective dynamical equations. Behaviors of these nodes are usually coupled according to the network topology. In real world applications, a great number of practical systems can be represented by models of complex networks, such as internet, world wide web, food webs, electric power grids, cellular and metabolic networks, scientific citation networks, social networks, protein interaction networks, and so on. So far, complex dynamical network has been one of the most popular topics in the areas of stabilization, synchronization, robustness, diffusion, passivity, dissipativity, bifurcation and so on. Recently, much research interest in the theory and applications of complex networks has been aroused in many fields of science and technology. Delayed neural networks, as special complex networks, have also been intensively studied by Arik (2004, 2005), Faydasicok and Arik (2013), Liu, Wang, and Liu (2008b) and Lu, Ho, and Liu (2007). For instance, Yuan, Luo, Jiang, Wang, and Fang (2007) proposed the complex dynamical network model, which is always uniformly asymptotically stable about its equilibrium. Moreover, stability analysis and decentralized control problems are addressed for linear and sector-nonlinear complex dynamical networks in Duan, Wang, Chen, and Huang (2008).

Synchronization is a method to synchronize two identical chaotic systems with different initial conditions. It is widely used in the area of secure communications, image processing, harmonic oscillation generation, language emergence development, biological systems, chemical reactions, structure engineering, information processing, power converts, by taking into account of their complicated dynamical behaviors such as complex dynamical networks. Based on the applications of synchronization with complex dynamical networks, synchronization problem for complex dynamical networks with switching topology from a switched system point of view is considered in Zhao, Hill, and Liu (2009). Further, the synchronization of complex dynamical networks with system delay and multiple coupling delays via impulsive distributed control was studied in Guan, Liu, Feng, and Wang (2010), by the concept of

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control topology introduced to describe the whole controller structure, which consists of some directed connections between nodes. Zhang, Xu, Chu, and Lu (2010), considered the problem of robust global exponential synchronization for a class of complex networks with time-varying delay couplings and each node in the network is composed of a class of delayed neural networks described by a nonlinear delay differential equation of neutral-type. Meanwhile Li, Zhang, Hu, and Nie (2011) considered the problem of sampled-data synchronization control for a class of general complex networks with time-varying coupling delays with a rather general sector like nonlinear function is used to describe the nonlinearities existing in the network. Recently, pth moment exponential synchronization of coupled memristor-based neural networks with both time-varying discrete delays and unbounded distributed delays under time-delayed impulsive control was investigated in Yang, Cao, and Qiu (2015), by using the Lyapunov functional method and some inequality techniques. The cluster synchronization was studied for array of hybrid coupled neural networks in Cao and Li (2009). Moreover, Rakkiyappan and Sakthivel (2014) studied the problem of cluster synchronization for Lur'e type Takagi–Sugeno fuzzy complex networks with probabilistic time-varying delay using Kronecker product with convex combination technique.

A set of linear systems with transitions between models determined by a Markov chain in a finite set mode is known as Markovian jump system. The neural networks may have been a finite modes and the modes may switch from one to another at different times and it is shown that the switching between different neural network models can be governed by a Markov chain. Additionally, Markov chains have also been widely used as a generic framework for modeling gene networks. So due to extensive applications of such systems in manufacturing systems, power systems, communication systems and network-based control systems, etc. Recently, many works have been reported about Markovian jump systems. For instance Karimi (2012) studied the problem of a sliding-mode approach for exponential H_∞ synchronization problem for a class of master–slave time-delay systems with both discrete and distributed time-delays, norm bounded nonlinear uncertainties and Markovian switching parameters. Recently, Yi, Wang, Xiao, and Huang (2013), studied the synchronization problem of complex dynamical networks with stochastic delay which switches stochastically among several forms of time-varying delays with both the discrete and distributed delays as well as the Markovian jump parameters. In Cui, Fang, and Zhang (2013), stabilization and synchronization control for Markovian jumping neural networks with mode-dependent mixed time delays subject to quantization and packet dropout was considered. It is significant to point out that all of the above mentioned references assume that the information on transition probabilities in the jumping process is completely known. However, in most cases, the transition probabilities of Markovian jump systems are not exactly known. Hence, it is of great importance to investigate the Markovian jump system with partly unknown transition probabilities. Ma, Xu, and Zou (2011), addressed the problems of stability and synchronization for a class of Markovian jump neural networks with partly unknown transition probabilities. Recently, Zhang, Fang, Miao, Chen, and Zhu (2013), studied the exponential synchronization problem of Markovian jump genetic oscillators with partly unknown transition probabilities. In addition, Chandrasekar, Rakkiyappan, Rihan, and Lakshmanan (2014), considered the problem of exponential synchronization of Markovian jumping neural networks with partly unknown transition probabilities via stochastic sampled-data control. So studies on synchronization and the performance for Markovian jump systems with partly unknown transition probabilities are of both theoretical and practical importance.

It is well known that impulsive effects are widespread phenomena in many systems such as computer networks, automatic control systems, signal processing systems and telecommunications. Therefore, the study of complex networks with impulsive effects is important for understanding the dynamical behaviors of real networks. In recent years, synchronization of impulsive complex dynamical networks has been investigated by many researchers. For instance, Li and Rakkiyappan (2013) and Li and Fu (2011), studied the Synchronization of chaotic delayed neural networks with impulsive controller. Recently, Zheng (2015), investigated the problem of impulsive complex projective synchronization for drive-response complex-variable dynamical networks with complex coupling, and the dynamical networks with and without delay complex-variable system nodes. To the best of our knowledge, there are few problems that deal with the impulsive synchronization of coupled neural networks, which motivates our present study.

Motivated by the above existing literature, the main contributions of this paper are as follows:

1. The general model of impulsive synchronization for Markovian jumping randomly coupled neural networks with partly unknown transition probabilities is introduced. By designing a novel Lyapunov functional, an impulsive synchronization criterion is established in terms of LMIs which can be solved efficiently by using the optimization algorithms. In addition, the control objective is that the trajectories of the slave system by designing suitable control schemes track the trajectories of the master system with impulsive effects have been utilized to strengthen this paper.

2. As mentioned in the previous works (Yang, Cao, & Lu, 2012a, 2012b, 2013), the authors have discussed the synchronization for coupled neural networks by using the double integral terms. But in our paper, the LKF is constructed as in $W_0(x_t, t, r(t))$ and $W_{\bar{l}}(x_t, t, r(t))$ to handle the multiple integral approach as compared with Yang et al. (2012a, 2012b, 2013) which has been used to reduce the computational burden in the theoretical aspects. Moreover, in the recent existing literature, so far, little consideration has been paid by assuming the partly unknown transition probabilities to analyze the impulsive synchronization of coupled neural networks which motivates the present study.

3. Finally, the effectiveness of the proposed methodology are confirmed on extensively tested examples.

The rest of this paper is organized as follows. In Section 2, the controlled synchronization problem is described and some preliminaries are introduced. In Section 3, the impulsive synchronization problem with partly unknown transition probabilities is studied and some sufficient conditions are developed. In Section 4, illustrative examples are provided to demonstrate the effectiveness of the proposed criteria and finally, conclusions are drawn in Section 5.

Notations: In the sequel, if not explicitly stated, matrices are assumed to have compatible dimensions. I denotes the identity matrix with appropriate dimension. The Euclidean norm in $\mathbb{R}^n$ is denoted as $\|\cdot\|$, accordingly, for vector $x \in \mathbb{R}^n$, $\|x\| = x^T x$, where T denotes transposition. $A = (a_{ij})_{m\times m}$ denotes a matrix of $m \times m$-dimension. $A > 0$ or $A < 0$ denotes that the matrix is symmetric and positive or negative definite matrix. $\lambda_{\max}(A)$ is the maximum eigenvalue of symmetric matrix A. $\mathbf{E}\{.\}$ stands for the mathematical expectation.

2. Problem description and preliminaries

Let $\{r(t), t \geq 0\}$ be a right-continuous Markov chain on the probability space taking values in a finite state space $\mathcal{S} = \{1, 2, \ldots, \tilde{N}\}$ with generator $\Pi = (\pi_{ij})_{\tilde{N}\times\tilde{N}}$ given by

$$P\{r(t+\Delta t) = j | r(t) = i\} = \begin{cases} \pi_{ij}\Delta t + O(\Delta t), & \text{if } i \neq j, \\ 1 + \pi_{ij}\Delta t + O(\Delta t), & \text{if } i = j, \end{cases}$$