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Exponential synchronization criteria for Markovian jumping neural networks with time-varying delays and sampled-data control

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ABSTRACT

This paper deals with the problem of exponential synchronization of Markovian jumping neural networks with time-varying delays and variable sampling control. Several delay-dependent synchronization criteria are derived to ensure the convergence of the error systems, that is, the master systems stochastically synchronized with the slave systems. By employing an improved Lyapunov–Krasovskii functional (LKF) with the triple integral terms and combining the convex technique, two new sufficient conditions are derived to guarantee that a class of delayed neural networks (DNNs) to be globally exponentially stable. The information about the lower bound of the discrete time-varying delay is fully used in the LKF. Moreover, the conditions obtained in this paper are formulated in terms of linear matrix inequalities (LMIs), which can be efficiently solved via standard numerical software. The maximum sampling intervals are obtained based on the design of mode-independent controller. Finally, three numerical examples are given to demonstrate the efficiency of the proposed theoretical results.

1. Introduction

In the past decades, considerable attention has been devoted to the study of neural networks because they can be used to solve certain problems related to signal processing, static image treatment, image processing, pattern recognition, optimization and associative memory design. Although neural networks can be implemented by very large scale integrated circuits, there inevitably exist some delays in neural networks due to the limitation of the speed of the transmission, switching of signals and threshold value of the communication line. It is well known that time-delay is usually a cause of instability and oscillations of recurrent neural networks. Therefore, the problem of stability of recurrent neural networks with time-delay is of importance in both theory and practical applications. Since the Lyapunov functional approach can present simple and delay-independent results for the considered time-delay systems, while the Lyapunov–Krasovskii functional (LKF) has been widely utilized because its analytical procedure fully depends on the information of delays. With the help of the linear matrix inequality (LMI) approach, a number of research works have been devoted to analysis and synthesis of neural networks with various types of delays, such as stability analysis, passivity analysis, and state estimation; and significant progress has been made in the literature ([1–3] and references therein).

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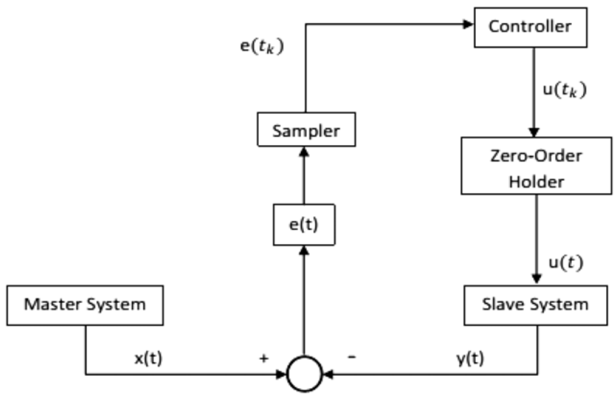

Fig. 1. Master–slave synchronization scheme under sampled-data feedback controller.

Markovian jump systems can be defined as a special class of dynamical systems with finite mode operation due to random changes in their structure, such as component failures or repairs, sudden environmental disturbance, changing subsystem interconnections. The applications of the Markovian jump systems can be found in economic systems, modeling production system, network control systems, manufacturing systems, communication systems and so on. In recent years, there have been lots of research work on the stability analysis for neural networks with Markovian jump parameters, see for Refs. [4–11]. Moreover, the problems of $\mathcal{H}_\infty$ finite-time boundedness and finite-time $\mathcal{H}_\infty$ state feedback stabilization for Markov jump systems with partially known transition probabilities were discussed in [12]. By using the free-connection weighting matrices approach, less conservative sufficient conditions on stabilization of Markovian jump systems with partial information on transition probability were studied in [13]. The authors in [14] have studied about the stabilization and synchronization control of Markovian jumping neural networks with mode-dependent mixed time delays subject to quantization and packet dropout. In [15], the authors discussed the adaptive synchronization for stochastic neural networks of neutral-type with mixed time-delays.

Because of the rapid development of the digital hardware technologies, the sampled-data control method, whose the control signals are kept constant during the sampling period and are allowed to change only at the sampling instant, has been more imperative than other control approaches. In addition, in order to make full use of modern computer technique, the sampled-data feedback control is applied to synchronize DNNs. The block diagram of master–slave DDNs with a sampling controller is shown in Fig. 1.

Sampled-data systems have been studied widely over the past decades and three main approaches (namely, lifting technique approach, input delay approach and impulsive model approach) have been used for sampled-data stabilization. The first one is based on lifting [16], in which the problem is changed into the corresponding finite-dimensional discrete-time problem while maintaining the inter-sampling information of the system. The second approach is based on modeling the sampled-data system as a continuous-time system with a delayed control input [17]. In this case, the solution is obtained in terms of differential Riccati equations with jumps. These approaches give necessary and sufficient conditions and lead to equivalent solutions. The third approach is based on the impulsive modeling of sampled-data systems in which a time-varying periodic Lyapunov function is used [18]. It is worthwhile to mention that, in [17,19], a new approach to dealing with the sampled-data control problems has been proposed by converting the sampling period into a time-varying but bounded delay. By this inspiration, in [20], the exponential synchronization sampled-data control problem has been studied for neural networks with time-varying mixed delays. Furthermore, many researchers have implemented the sampled-data control scheme to solve control problems in various systems such as chaotic system [21], fuzzy system [22], neural networks [23] and so on.

On the other hand, the sampled-data control theory has been received much attention due to the powerful applications in the field of engineering. For example [24], the robust sampled-data $\mathcal{H}_\infty$ control problem has been investigated for active vehicle suspension systems. The problem of sampled-data synchronization for Markovian jump neural networks with time-varying delay using sampled-data control was investigated in [25]. In [26], the authors have discussed the problem of exponential synchronization of neural networks with mixed delays using sampled-data feedback control. The sampled-data control or estimation problems and other control problems have been studied in [27–31]. In [30], the authors pointed out the synchronization of chaotic neural networks with time delay in the leakage term and parametric uncertainties based on sampled-data control. The problem of exponential state estimation for delayed recurrent neural networks with sampled-data control have been discussed in [31]. The problem of sampled-data state estimation for delayed neural networks with Markovian jumping parameters has been discussed in [32]. In [17,33], the authors have discussed the problem of sampled-data synchronization of neural networks with discrete and distributed delays under variable sampling in the framework of the input delay approach.

Since the pioneering work of Pecora and Carroll [34], the topic of chaos synchronization has attracted great interest in both theoretical studies and practical applications. Chaos synchronization has been widely investigated due to its