Chapter 4.20
Synchronization of Uncertain Neural Networks with H_∞ Performance and Mixed Time-Delays

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ABSTRACT

An exponential H_∞ synchronization method is addressed for a class of uncertain master and slave neural networks with mixed time-delays, where the mixed delays comprise different neutral, discrete and distributed time-delays. An appropriate discretized Lyapunov-Krasovskii functional and some free weighting matrices are utilized to establish some delay-dependent sufficient conditions for designing a delayed state-feedback control as a synchronization law in terms of linear matrix inequalities under less restrictive conditions. The controller guarantees the exponential H_∞ synchronization of the two coupled master and slave neural networks regardless of their initial states. Numerical simulations are provided to demonstrate the effectiveness of the established synchronization laws.

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INTRODUCTION

In the last few years, synchronization in neural networks (NNs), such as cellular NNs, Hopfield NNs and bi-directional associative memory networks, has received a great deal of interest among scientists from various fields (Chen & Dong,1993; Sun et al., 2007; Wang et al., 2008; Cheng et al., 2006; Cao et al., 2007). In order to better understand the dynamical behaviours of different kind of complex networks, an important and interesting phenomenon to investigate is the synchrony of all dynamical nodes. In fact, synchronization is a basic motion in nature that has been studied for a long time, ever since the discovery of Christian Huygens in 1665 on the synchronization of two pendulum clocks. The results of chaos synchronization are utilized in biology, chemistry, secret communication and cryptography, nonlinear oscillation synchronization and some other nonlinear fields. The first idea of synchronizing two identical chaotic systems with different initial conditions was introduced by Pecora and Carroll (Pecora & Carroll, 1990), and the method was realized in electronic circuits. The methods for synchronization of the chaotic systems have been widely studied in recent years, and many different methods have been applied theoretically and experimentally to synchronize chaotic systems, such as feedback control (Fradkov & Pogromsky, 1996; Gao et al., 2006; Karimi & Maass, 2009; Wen et al., 2006; Hou et al., 2007; Lu & van Leeuwen, 2006), adaptive control (Liao & Tsai, 2008; Feki, 2003; Wang et al., 2006a; Fradkov & Markov, 1997; Fradkov et al., 2000), backstepping (Park, 2006) and sliding mode control (Yan et al., 2006; García-Valdovinos et al., 2007). Recently, the theory of incremental input-to-state stability to the problem of synchronization in a complex dynamical network of identical nodes, using chaotic nodes as a typical platform was studied in (Cai & Chen, 2006).

On the other hand, in practice, due to the finite switching speed of amplifiers or finite speed of information processing, time delays including delays in the state (discrete delays) or in the derivative of the state (neutral delays) are often encountered in hardware implementation (Hale & Verduyn Lunel, 1993; Fridman, 2006; Gu, 2003; Park, 1999; Gao et al., 2008), which may be a source of oscillation, divergence, and instability in NNs. Another type of time-delays, namely, distributed time-delays, have begun to receive research attention (Wang et al., 2006b; Wang et al., 2006c). The main reason is that, since a NN usually has a spatial nature due to the presence of an amount of parallel pathways of a variety of axon sizes and lengths, continuously distributed delays should be introduced in modelling of the NNs over certain duration of time such that the distant past has less influence compared to the recent behaviour of the state (Wang et al., 2006b). Therefore, the stability problems of NNs with mixed time-delays have gained great research interest (Wang et al., 2007; Cao et al., 2006; Cao & Wang, 2005; Wang & Cao, 2009; Song & Wang, 2008; Liu et al., 2007, Wang et al., 2006d). Recently, both delay-independent and delay-dependent sufficient conditions have been proposed to verify the asymptotical or exponential stability of delayed NNs, see for instance the references (He et al., 2006; Zhang et al., 2005; Wang et al., 2005a; Xu et al., 2005; Xu et al., 2006; Lou et al., 2006; He et al., 2005; Mou et al., 2008a; Mou et al., 2008b; Ho et al., 2006) and references therein. Furthermore, many results have been reported on the stability analysis issue for various NNs with distributed time-delays, such as recurrent NNs (Liang & Cao, 2007; Liang & Cao, 2006), bi-directional associative memory networks (Liang & Cao, 2004), Hopfield NNs (Zhao, 2004a), cellular NNs (Zhao, 2004b). It is noted that both discrete and distributed time delays have been recently considered in the references (Wang et al., 2006b; Wang et al., 2006c), (Song & Wang, 2008) and (Wang et al., 2005a). It can be realized that in Huang et al. (2006), Karimi and Maass (2009) and others (Cao et al. 2008; Yu et al., 2008; Liang et al., 2008; Wang et al., 2005b; Huang et al., 2008) several sufficient conditions in terms of LMIs were presented to solve the synchronization and estimation problems of NNs with time-delays. The authors in (Huang et al., 2008) studied the exponential synchronization problem for a class of chaotic Lur'e systems by using delayed feedback control by employing an integral inequality and introducing several slack variables to reduce the conservatism of the developed synchronization criterion. In (Liang et al., 2008), the problem of synchronization for stochastic discrete-time drive-response networks with time-varying delay was investigated