Chapter 14

Type-2 Fuzzy Sliding Mode Synchronization

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ABSTRACT

This chapter presents an adaptive interval type-2 fuzzy neural network (FNN) controller to synchronize chaotic systems with training data corrupted by noise or rule uncertainties involving external disturbances. Adaptive interval type-2 FNN control scheme and sliding mode approach are incorporated to deal with the synchronization of non-identical chaotic systems. In the meantime, based on the adaptive fuzzy sliding mode control, the Laypunov stability theorem has been used to testify the asymptotic stability of the chaotic systems. The chattering phenomena in the control efforts can be reduced and the stability analysis of the proposed control scheme will be guaranteed in the sense that all the states and signals are uniformly bounded and the external disturbance on the synchronization error can be attenuated. The simulation example is included to confirm validity and performance of the advocated design methodology.

INTRODUCTION

In general, the synchronization phenomenon is happened when two, or more, chaotic oscillators are coupled, or when a chaotic oscillator drives another chaotic oscillator. In the other word in the synchronization problem the output of the drive system is used to control the response system so that the output of the response system follows the output of the drive system asymptotically. Although chaotic systems have deterministic behavior, they are extremely sensitive to initial conditions and difficult to predict. Motivated by potential applications in chaos synchronization, such as communication theory, biological engineering, pattern recognition and information processing, control chaotic dynamics has received and

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increasing interest. The OGY method, a model-free chaos control method, was proposed to stabilize one of the unstable periodic orbits by perturbing an accessible system parameter over (Ott, Grebogi, & Yorke, 1990). Besides, many chaos control strategies have been presented based on feedback control technologies as well as sliding mode control (SMC) (Chang, 2001; Kim, Yang, & Hong, 2003; Leu, Lee, & Wang, 1999; Li & Tong, 2003; S. C. Lin & Chen, 1994; Palm, 1992; Sastry & Bodson, 1989; Chi Hsu Wang, Lin, Lee, & Liu, 2002; Chi Hsu Wang, Liu, & Lin, 2002; L. X. Wang, 1993, 1994; L. X. Wang & Mendel, 1992; W. Y. Wang, Chan, Hsu, & Lee, 2002; Yoo & Ham, 1998; Zheng, Liu, Tong, & Li, 2009). Recently, the study of chaos synchronization has become a hot spot in the nonlinear dynamics field and researchers in this field have explored a variety of problems on chaos synchronization, such as the stability conditions for chaos synchronization, the realization for a successful synchronization and the applications of chaos synchronization.

In recent years, some chaos synchronizations based on fuzzy systems have been proposed (Noroozi, Roopaei, Balas, & Lin, 2009; Noroozi, Roopaei, Karimaghaee, & Safavi, 2010; Noroozi, Roopaei, & Zolghadri Jahromi, 2009; Mehdi Roopaei & Jahromi, 2008; Mehdi Roopaei, Zolghadri Jahromi, & Jafari, 2009; Mehdi Roopaei, Zolghadri, John, & Lin, in press; Mehdi Roopaei, Zolghadri, & Meshksar, 2009; Zadeh, 1965). The fuzzy set theory was initiated by Zadeh (Chen, Lee, & Chang, 1996). Recently, intelligent control approach has been done on applications of FNNs, which combine the capability of fuzzy reasoning to handle uncertain information and the capability of artificial neural networks to learn from processes. The FNNs do not require mathematical models and have the ability to approximate nonlinear and uncertainties systems. Therefore, there were many researches using FNNs to represent complex plants and construct advanced controllers (Chen, Tseng, & Uang, 2000; Golea, Golea, & Benmahammed, 2003; Hojati & Gazor, 2002; Kim et al., 2003; Kosko, 1994; Kovacic, Balenovic, & Bogdan, 1998; C. C. Lee, 1990; H. Lee & Tomizuka, 2001; Leu et al., 1999; Li & Tong, 2003; J. M. Mendel, 2004; Nguang & Shi, 2003; Sastry & Bodson, 1989; Tseng & Chen, 2001; C. H. Wang, T. C. Lin et al., 2002; C. H. Wang, H. L. Liu et al., 2002; J. S. Wang & Lee, 2002; L. X. Wang, 1993, 1994, 1997; L. X. Wang & Mendel, 1992; Yang & Zhou, 2005; Zheng et al., 2009) based on the back propagation algorithm. Currently, there were only few works to analyze and simulate the type-2 FNN (Hsiao, Li, Lee, Chao, & Tsai, 2008; Karnik, Mendel, & Liang, 1999; Kheireddine, Lamir, Mouna, & Hier, 2007; Tsung Chih Lin, 2009; Tsung Chih Lin, Kuo, & Hsu, in press; Tsung Chih Lin, Liu, & Kuo, 2009; J.M Mendel, 2007; Jerry M. Mendel, John, & Liu, 2006; J. M. Mendel & John, 2000; C. H. Wang, Cheng, & Lee, 2004)

As the membership functions for the type-1 fuzzy sets contain no uncertainty information, the control problem cannot be directly handled if the nonlinear system has the rule uncertainty will be existed in following three possible ways, (i1 the words that are used in antecedents and consequents of rules can mean different things to different people; (2) consequents obtained by polling a group of experts will often be different for the same rule because the experts will not necessary be in agreement; and (3) noisy training data. Type-2 FLSs, are very useful where it is difficult to determine an exact membership function, and there are measurement uncertainties. It is known that type-2 fuzzy sets enable modeling and minimizing the effects of uncertainties in rule-based fuzzy logic systems. Type-2 fuzzy sets are able to model such uncertainties because their membership functions are themselves fuzzy. A type-1 fuzzy set is a special case of a type-2 fuzzy set. A type-2 FLS is again characterized by IF-THEN rules, but its antecedent or consequent sets are now of type-2 (Hsiao et al., 2008; Karnik et al., 1999; Kheireddine et al., 2007; Tsung Chih Lin, 2009; J.M Mendel, 2007; Jerry M. Mendel et al., 2006; J. M. Mendel & John, 2000; C. H. Wang et al., 2004). The type-2 FLS has been successfully applied to fuzzy neural network, VLSI testing (Tsung Chih Lin, 2009) and fuzzy controller designs.

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