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Improved switching controllers for finite-time synchronization of delayed neural networks with discontinuous activations☆

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Abstract

This paper considers time-delayed and discontinuous neural networks described by a class of functional differential inclusions. Without assuming the boundedness and monotonicity of the discontinuous activation functions, the finite-time synchronization control of the drive-response neuron system is studied. First, we propose a set of novel switching state-feedback controllers and switching adaptive controllers. Second, we give some sufficient conditions to control the synchronization error to converge zero in a finite time. Moreover, these conditions are easily checkable. The dynamic analysis here employs the set-valued analysis, the extended Filippov-framework, the famous finite-time stability theorem and the generalized Lyapunov functional method. Finally, numerical examples and computer simulations are presented to confirm and demonstrate the theoretic findings.

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1. Introduction

In 2003, Prof. Forti and Nistri firstly introduced the differential inclusion theory to investigate the neural networks with discontinuous or non-Lipschitz activation functions [1]. Since this pioneering work, neural networks with discontinuous activation functions have received more and more research attention [2–12]. In fact, neural networks with discontinuous neuron activations are significant and do frequently occur in applications. For example, when dealing with dynamical neuron systems possessing high-slope nonlinear elements, it is often advantageous to model them with discontinuous activations. Moreover, the neural networks with discontinuous activations are ideal models to solve constrained optimization problems, linear or nonlinear programming problems, and various control problems [1,13–15]. As shown by Forti and Nistri [1,2], the analysis of neural network with discontinuous activation is also able to reveal many specially interesting and crucial features of the dynamics, such as the presence of sliding modes along discontinuity surfaces and the phenomenon of convergence in finite time toward the equilibrium point or periodic orbit. In recent years, under the Filippov differential inclusion framework, the studies of neural networks possessing discontinuous activation functions mainly focus on their dynamical behaviors. However, most of the previous results on dynamical behaviors of neural networks with discontinuous neuron activations were mainly concerned with the existence and convergence of periodic orbits or almost periodic orbits or even equilibrium point. It should be pointed out that, due to the jump discontinuities of neuron activations, the neural network system may exhibit some unstable behaviors such as oscillation and chaos. We also note that these unstable behaviors will become more apparent if time-delay is considered in neuron signals because of their finite processing or reaction time. So an interesting problem we must face is how to stabilize or synchronize unstable (e.g., chaotic or oscillatory) neural network system with time-delays and discontinuous neuron activations. To the best of our knowledge, the results concerning synchronization especially on finite-time synchronization of time-delayed neural networks with discontinuous activations are still few.

Usually, two coupled systems consisting of drive system and response system are said to be synchronized if they evolve according to exactly the same dynamics. By controlling the trajectories of the synchronization error states converge to zero, we can understand an unknown dynamical system from the well-known dynamical system. Until now, many classes of synchronization have been presented, such as, asymptotic synchronization, exponential synchronization, quasi-synchronization, identical synchronization, lag synchronization, pinning synchronization, anticipated synchronization, periodic synchronization, chaos synchronization, phase synchronization, anti-synchronization, finite-time synchronization and so on. Recently, the synchronization control of discontinuous neural network systems (for example, dynamical neuron systems whose activation functions possess jump discontinuities and memristive dynamical neuron systems) has become an active research topic. Despite the fact that the study of synchronization for discontinuous neural network is not an easy work, some theoretical results have already been reported. In [16], by constructing suitable Lyapunov functionals, the authors investigated the exponential synchronization problem of delayed neural networks with discontinuous activations. Based on feedback controllers and adaptive controllers, the paper [17] was concerned with the complete synchronization, exponential synchronization and pinning synchronization issues for linearly coupled delayed neural networks with discontinuous activation. In [18,19], some quasi-synchronization results of neural networks with discontinuous activations were obtained. By utilizing approximation approach, the authors of [20] dealt with the complete synchronization problem of the delayed neural networks