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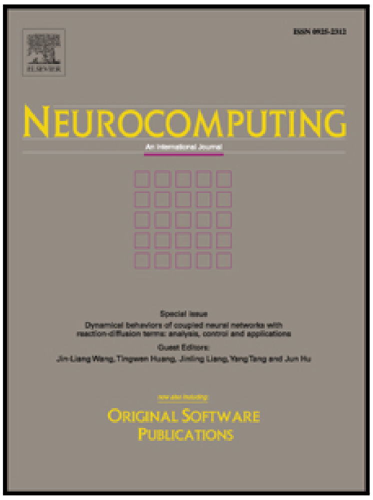


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# Fixed-Time Synchronization for Coupled Delayed Neural Networks With Discontinuous or Continuous Activations

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**Abstract**

This paper is concerned with fixed-time synchronization of coupled delayed neural networks with discontinuous or continuous activation functions. Two discontinuous control protocols under undirected or directed topologies are proposed to guarantee that coupled delayed neural networks achieve synchronization with a desired trajectory in fixed time, respectively. Several sufficient criteria for fixed-time synchronization are obtained. Furthermore, an upper bound of the settling time is theoretically estimated, which is independent on initial conditions. Finally, two numerical examples are given to illustrate the effectiveness of the synchronization criteria.

*Keywords:* Neural networks, time-delays, fixed-time synchronization, continuous activations, discontinuous activations.

## 1. Introduction

In the past decades, neural networks have attracted intensive attention due to their broad applications in signal processing, computer vision, natural language processing and optimal calculation [1, 2, 3, 4, 5, 6]. In biological systems, it is found that neurons of visual nervous systems are layered coupling [7]. Synchronization has been observed in coupled neuron systems. It has been shown evidence that the presence or absence of synchrony in the brain is often linked to a specific brain function or a critical physiological state such as epilepsy [8] and Parkinsons disease [9, 10] in neuroscience [11]. Thus, synchronization of coupled neural networks has gained considerable attention.

It is well known that time delay is unavoidable due to information transmission from one system to another and the limited bandwidth [12, 13, 14]. Hence, synchronization of coupled delayed neural networks has been brought into focus [15, 16]. In [15], pinning synchronization of coupled neural networks with both current-state coupling and distributed-delay coupling was studied via an impulse pinning control. Some sufficient conditions were obtained to guarantee synchronization of coupled delayed neural networks with reaction-diffusion effects in [16]. However, only neural networks with continuous activation functions were studied. In fact, neural networks with discontinuous activation functions are more important, which frequently arise in practice [17]. As mentioned in [18], an example of neural networks was introduced in [19] for solving linear and nonlinear programming problems. Constraint neurons with diode-like input-output activations were considered, in which the diode was required to have a very high slope, approximating the discontinuous characteristic of an ideal diode. When activation functions are not continuous, some existing results on synchronization of coupled neural networks including those in the former mentioned papers fail to deal with the case. It should be pointed out that neural networks with discontinuous activations are a class of special equations with discontinuous right-hand side. The uniqueness of the solution cannot be guaranteed [20]. The Filippov solutions have been utilized as a feasible approach in dealing with the discontinuous dynamical systems. There have been some results about synchronization of discontinuous delayed neural networks. In [21], complete synchronization was achieved for a class of neural networks with time-varying delays and discontinuous activations. In [22], a class of general neural networks with discontinuous activation functions and distributed delays was studied. Discontinuous controllers were design to achieve synchronization.

When the time goes infinity, asymptotic synchronization is considered in most of the aforementioned results. In practical applications, it is important to achieve synchronization in finite time to meet specific requirements. Thus, the concept of finite-time synchronization occurs naturally and draws considerable attention [23]. For example, the finite-time synchronization problem was addressed in [24], where agents have the first-order dynamics. Based on homogenous systems theory, finite-time synchronization with the second-order nonlinear dynamics were

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