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Finite-time modified projective synchronization of memristor-based neural network with multi-links and leakage delay

Xiaoli Qin[a,b], Cong Wang[a,c], Lixiang Li[d,*], Haipeng Peng[d], Yixian Yang[d], Lu Ye[b]

[a] School of Software, Beijing University of Posts and Telecommunications, Beijing 100876, China
[b] Institute of Scientific and Technical Information, Chinese Academy of Tropical Agricultural Sciences, Haikou 571101, China
[c] Key Laboratory of Trustworthy Distributed Computing and Service, Ministry of Education, Beijing University of Posts and Telecommunications, Beijing 100876, China
[d] National Engineering Laboratory for Disaster Backup and Recovery, Beijing University of Posts and Telecommunications, Beijing 100876, China

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ABSTRACT

This paper investigates the finite-time modified projective synchronization problem of memristor-based neural networks with multi-links (MNNLs). And leakage and discrete time-varying delays (mixed delays) are considered in the MNNLs model. By designing a delay-dependent controller and an adaptive controller, the drive-response systems can reach finite-time modified projective synchronization with arbitrary constants. Based on two kinds of finite-time stability theories and some differential inequalities, several finite-time modified projective synchronization criteria are obtained with the Lyapunov stability method. Besides, several corollaries about the special cases of finite-time modified projective synchronization are given along with the proposed theorems. At last, three numerical simulations are given to illustrate the effectiveness and verify the correctness of our results.

1. Introduction

The memristor is considered as the fourth basic electronic devices besides resistance, capacitance, inductance. The first memristor was created in HP Labs [1] in 2008, and it was proposed theoretically by Chua [2] in 1971. There are two main properties of the memristors. The first is resistance variability, i.e. the memristor can change its own properties when an external signal passes [3]. The second is memory property, i.e. the memristor can adjust its memory information according to its resistance state transitions. Since these advantages of variable resistance and memory property are similar to the synapse of biological neurons, the researches on memristor and its applications have attracted much attention. The main research point is that memristors are used to simulate the synapses of neurons, and the characteristics of memristance is closer to the synapses. In order to simulate biological neural networks better, more realistic artificial neural networks may be constructed with memristors, and these can help us study biological neural networks better. Therefore, exploring the value of the memristors and constructing a universal memristor-based neural network model is an important purpose for the scholars. A sketch map shows the simple relationship of partial biological neural networks, partial memristor-based neural networks and the memristor in Fig. 1. In recent years, many results appear to simulate of biological neural networks more realistically by designing memristor-based neural networks (MNNs) [4–7]. Until now, there have been more and more achievements about the MNNs models, such as memristor-based neural networks with multiple delays [8–10], complex-valued memristor-based neural networks [11], memristor-based BAM neural networks [12,13], memristor-based Cohen-Grossberg neural networks [14,15], fractional-order MNNs [16,17] and so on. However, these neural networks do not consider the multi-links between neurons. Especially a new type of memristor-based neural network model with multi-links (MNNLs) [18] was proposed in 2018. The MNNLs can simulate the behaviors of the neurons synapses better, which is based on the multiple connectivity characteristics of biological neurons synapses.

On the other hand, the synchronization of MNNs is a special case of network stability, and its application areas are also numerous, such as secure and efficient data transmission, pseudo-random number generator [19], chaotic password generator for image encryption [20], anti-attack behavior of network synchronization [21], etc. In the research of system synchronization control, different controllers can be designed to achieve different kinds of synchronization and meet different corresponding requirements. For example, if we want to know the time of synchronization control, finite-time synchronization [21,22] can be chosen to meet this

* Corresponding author.
E-mail address: li_lixiang2006@163.com (L. Li).

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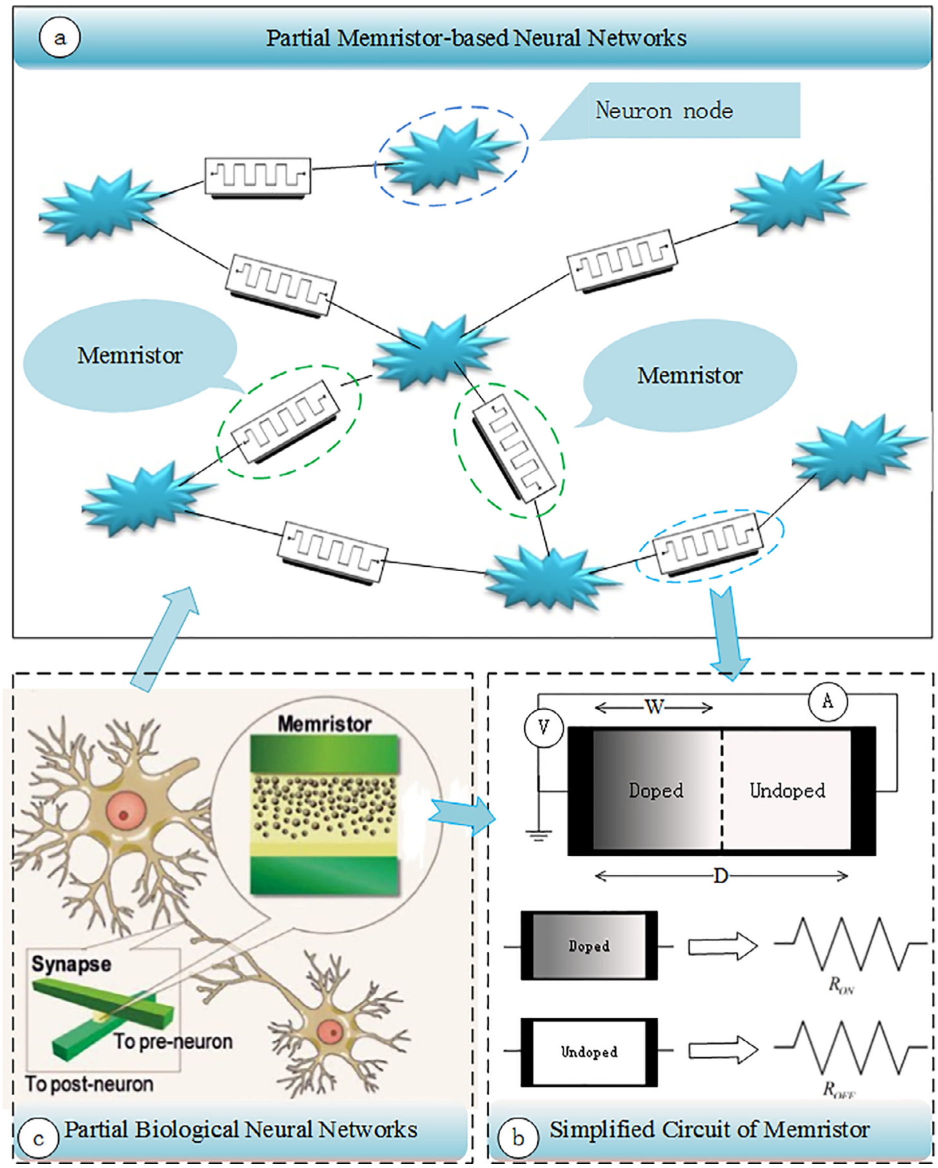

Fig. 1. A sketch map of partial biological neural networks, partial memristor-based neural networks and the memristor. Subgraph (a) shows the partial memristor-based neural networks. Subgraph (b) shows the simplified circuit of the memristor. Subgraph (c) shows the partial biological neural networks with synapse and memristor.

requirement, otherwise asymptotic synchronization [23,24] is also good. If we require a more general type of synchronization, projective synchronization [25–27] is suited, complete synchronization and anti-synchronization [28] are its special cases. If we need the robustness of the controller, an adaptive controller [29] may be designed to meet. In our opinion, finite-time synchronization has more application value and prospect in our daily life, the adaptive control method is more practical, and the projective synchronization type is more widely applicable. In short, we can choose different types of system synchronization methods according to different requirements and different conditions in our daily life.

Meanwhile, the delays and perturbations may occur during signal generation and transmission between the neurons. For the purpose of describing the behaviors of biological neural network more similarly, many kinds of delays are introduced to the MNNs, including leakage delay [30,31], discrete time-varying delay [32,33] and distributed time-varying delay [30,34], even the stochastic perturbation [35]. Therefore, the network models should combine reasonable and meaningful delays so that their behaviors can be closer to those of the biological neural network.

As we know, the application is an important purpose of choosing network model, the type and the settling time of synchronization. In this paper, we study the finite-time projective synchronization of MNNLs with leakage delay and discrete time-varying delays. Leakage is a system leakage item and it exists in many network systems, but it has hardly been considered in the study of the MNNs models. And there are few studies on the finite-time modified projective synchronization of MNNLs with leakage delay. It can be applied in the fields of system control and image encryption, and these are the directions of our further research.

Motivated by the above analysis, we try to investigate the MNNLs with leakage and discrete time-varying delays, which is better to describe discrete time-varying delays and leakage delay in biological neural networks. The main contributions of this paper lie in three aspects: (a) Leakage delay is introduced to the MNNLs with discrete time-varying delays in order to describe the leakage item of neurons in biological neural networks. To the best of my knowledge, this model structure has not been considered. (b) A delay-dependent controller and an adaptive controller are designed to achieve the modified projective synchronization, and