Applied Mathematics and Computation 275 (2016) 213–228

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

Reliable anti-synchronization conditions for BAM memristive neural networks with different memductance functions

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ARTICLE INFO

Keywords:
Memristor
Chaos
Reliability
BAM neural network
Anti-synchronization

ABSTRACT

This paper is concerned with anti-synchronization results for a class of memristor-based bidirectional associate memory (BAM) neural networks with different memductance functions and time-varying delays. Based on drive-response system concept, differential inclusions theory and Lyapunov stability theory, some sufficient conditions are obtained to guarantee the reliable asymptotic anti-synchronization criterion for memristor-based BAM networks. The memristive BAM neural network is formulated for two types of memductance functions. Sufficient results are derived in terms of linear matrix inequalities (LMIs). Finally, the effectiveness of the proposed criterion is demonstrated through numerical example.

1. Introduction

A memristor is a two-terminal passive variable resistor whose value can be changed by varying the current passing through it and remembers the amount of current that has passed through it in the past. Prof. Leon Chua made an interesting observation in 1971 that led to his discovery of the memristor as the fourth basic circuit element see [5]. However, during the early days of its invention it did not attract much attention of researchers. But after the invention of TiO_2-based crossbar memory array which is developed by the Hewlett–Packard Labs in 2008 [26,27], the memristor circuits become very popular because of its unique superior properties and prospective promising applications in nonvolatile memory, artificial neural networks, chaotic circuits, programmable logic devices and signal processing and pattern recognition circuits etc. From the perspective of neurodynamic systems, the synapses among neurons in biological neural systems possess long-term memories, and in that the resistors cannot implement memory functions but with the use of memristors instead of resistors in the circuit of biological neural system is very much helpful in implementing memory functions perfectly, such an architecture can enable us to build a memristive neural system, which was able to facilitate to simulate the real brain. Recently, a general class of memristive neural systems with time delays is formulated and investigated in [31]. Global exponential stability of memristor-based recurrent networks with time-varying delays and globally Lipschitz continuous activation functions are studied in [30]. In the existing literature's, many researchers have constructed the memristor-based neural networks with promising applications, see [13,28,32].

On the other hand, BAM neural networks is an important type of neural networks which was introduced by Kosko in 1988 [14]. It has wide range of fascinating applications such as, image processing, pattern recognition, automatic control,

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http://dx.doi.org/10.1016/j.amc.2015.11.060
0096-3003/

associative memory, and combinatorial optimizations. Therefore, it has received much attention from scientists (see [3,6,20,23–25,38]) so it is meaningful and important to study the BAM neural networks. A general memristor-based BAM neural networks (MBAMNNs) with time-varying delays have been introduced and investigate the dynamic behaviors under the framework of Filippov's solution [2]. Also, time delays are often encountered in most of the dynamical systems such as signal transmission delay, signal processing and propagation delay due to integration and communication. The existence of time delays inherent in many physical processes and practical dynamical systems are often the sources of divergence, chaos, oscillation and instability by changing the dynamic characters of system dramatically. Thus, the study of dynamical behaviors of neural networks with time-delays has received much more attention among the researchers. Further, reliable control is used for enhancing robustness against possible component failures that occur in controllers or sensors and actuators. The main objective is to maintain the stability of closed-loop systems when there is a exist some component failures. Actuator failures may be uncertain, that is, it is not exactly known or in what manner it failed and how many actuators failed. In recent years, there have been a number of results in the literature on systems with various types of failures, see [12,18] and references therein. The problem of reliable dissipative control was investigated for a continuous-time singular Markovian system with actuator failure in [9]. The reliable synchronization problem for a general class of chaotic systems have been addressed in [15]. The synthesis problem of robust and reliable stabilization for linear systems with norm-bounded time-varying parameter uncertainty in the state and delayed-state matrices and also with actuator failures among a pre-specified subset of actuators was focused in [29].

In practice, the synchronization of dynamical systems should be treated as an important concept due to its potential applications in many different areas, see [7,21,35]. The significance of the function anti-synchronization of distinct dynamical systems is to make the anti-synchronicity behaviors hidden and the concept of synchronization is also a universal concept for dynamical systems. Pecora and Carroll in [22], presented a criterion of the sub-Lyapunov exponents to determine the synchronization of two dynamical systems connected with common signals. After that, the concept of synchronization leads to very active topic in nonlinear science and has been extended to different types of synchronization in both ordinary and delayed dynamical systems such as complete synchronization, generalized synchronization, phase synchronization, lag synchronization and even anti-phase synchronization (anti-synchronization: The state vectors of the synchronized systems have the same amplitude as but opposite signs to those of the driving system). The anti-synchronization of two different chaotic systems has been investigated in [17]. A theory for synchronization of multiple dynamical systems to specific constraints was presented from a theory of discontinuous dynamical systems in [19]. Based on nonsmooth analysis technology [10,11], master-slave synchronization problem of MNNs was established in [16] and [4] studied the global Mittag-Leffler stability and synchronization for fractional-order MNNs. The problem of global exponential synchronization for memristor based Cohen–Grossberg neural networks with time-varying discrete delay and unbounded distributed delay was concerned in [34]. Memristive recurrent neural networks are usual recurrent neural networks in which the parallel-memristors connection corresponding to the capacitors and memristors synaptic connection are used [37]. Zhang et al. [33] studied the anti-synchronization for a memristor-based neural networks with mixed time delays and reaction–diffusion terms. Recently, [36] concerned the global exponential anti-synchronization of chaotic memristive neural networks with time-varying delays and in [32], two different types of anti-synchronization algorithms are derived to achieve the exponential anti-synchronization of the coupled systems based on drive-response concept, differential inclusions theory and Lyapunov functional method. It should be mentioned that, the anti-synchronization results for memristor-based BAM neural networks has not been studied yet, this motivates our present study.

Based on the above discussions, we consider a class of memristive BAM NNs with different types of memductance functions and time-varying delays. The main contribution of this paper lies in the following aspects: (1) The anti-synchronization of the considered neural networks is derived using the reliable controllers. (2) The drive-response anti-synchronization is first time addressed between two different memristive BAM neural networks. (3) The main objective of this work is to obtain a robust feedback controller with an appropriate gain control matrix to guarantee the anti-synchronization of the closed loop system. We use the reliable controller to control the memristive slave system according to their master system successfully even though their parameters are unknown. (4) The main results are derived by utilizing the differential inclusion theory by driving the appropriate Lyapunov–Krasovskii functional (LKF) and using LMI technique. Finally we provide the numerical example to illustrate the effectiveness and applicability of the proposed results which demonstrates the importance of designing the reliable controllers, it can be effective one to guarantee the stability of system even though there exist some actuator failures.

The structure of this paper is outlined as follows. In Section 2, brief model descriptions of the memristive BAM NNs and some mathematical preliminaries are presented. Section 3 derives sufficient conditions for the anti-synchronization by constructing a suitable LKF for MBAMNNs with different kinds of memductance functions. The numerical simulations are presented to demonstrate the effectiveness of the proposed approach in Section 4. Finally, this paper ends with a conclusion in Section 5.

2. Problem description and preliminaries

In this section, we construct a general class of BAMNNs from the aspects of circuit theory and memristor physical properties, which reproduce the characteristic time hysteresis behavior of memristor devices. From Kirchoffs current law, the ith and jth