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New algebraic conditions for global exponential stability of delayed recurrent neural networks

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Abstract

The global exponential stability is further discussed for a class of delayed recurrent neural networks with Lipschitz-continuous activation functions. By constructing new Lyapunov functional and applying an elementary inequality technique, a set of new conditions with less restriction and less conservativeness are proposed for determining global exponential stability of the delayed neural network model with more general activation functions. The proposed results improve and generalize some previous reports in the literature. Several examples are also given to illustrate the validity and advantages of the new criteria.

Keywords: Global exponential stability; Delayed recurrent neural networks; Lyapunov functional; Bi-directional associative memory neural networks

1. Introduction

During the past several years, the convergence dynamics of delayed recurrent neural networks (DRNN) has been extensively studied because of the wider applications in various information processing. Many researchers, such as, for example, Jinde Cao [4–10,12,16], Cao and Dong [14], Mohamad and Gopalsamy [28], Arik and Tavsanoglu [1,2], Liao and co-authors [20–26] and so on, have been

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obtained many a criterion for checking the asymptotical stability [7–11,19,20,28] and exponential stability [1–4,6,12,16–18,21–23,25,26,29,30] of neural networks with and without delays. Several techniques have been introduced, and the combination of Lypunov-functional method with inequality technique [1,2,4–12,16–19,22,23,25,26,28–30] and the combination of Lypunov-functional method with LMI technique [3,20,21] have been widely adopted. Other technique adopted can be found in Ref. [24]. However, most results were yet restrained because of the complexity of nonlinear systems and the limitation of these approaches above. In this paper, new sufficient conditions for global exponential stability of a class of DRNNs will be given, which improve and generalize a set of results reported in the literature, for example, the results in Ref.[1,2,4–12,16,17,19,28–30]. In particular, applying our results to bi-directional associative memory neural networks with delays also yields a more practical condition for checking stability (which generalizes and improves those of [14,24]).

The rest of this paper is organized as follows: Formulation and preliminaries are presented in Section 2. Main results, that is, the criteria for global exponential stability, are investigated in Section 3. Several examples are given in Section 4 to demonstrate the effectiveness and advantage of our results, and in Section 5, some conclusions are drawn.

2. Formulation and preliminaries

Consider the following recurrent neural networks with delays:

$$\dot{x}_i(t) = -c_i x_i(t) + \sum_{j=1}^{n} a_{ij} f_j(x_j(t)) + \sum_{j=1}^{n} b_{ij} f_j(x_j(t-\tau_j)) + I_i, \quad i = 1, 2, \ldots, n, \tag{1}$$

where a_i and τ_i are nonnegative numbers representing the neuron charging time constants and axonal signal transmission delays, respectively; a_{ij} and b_{ij} stand for the weights of the neuron interconnections, and f_i and I_i are the activation functions of the neurons and the external constant inputs, respectively. Moreover, we assume that the initial condition of system (1) has the form

$$x_i(t) = \phi_i(t), \quad t \in [-\tau_i, 0], \tag{2}$$

where ϕ_i are continuous functions for $i = 1, 2, \ldots, n$.

Throughout the paper, we assume that the activation functions satisfy the following conditions:

(H1) $f_i (i = 1, 2, \ldots, n)$ is bounded on $\boldsymbol{R}$, that is, there exist positive constants $M_i (i = 1, 2, \ldots, n)$, such that $|f_i(x)| \leqslant M_i$, for any $x \in R$, $i = 1, 2, \ldots, n$.

(H2) There exist constants $\mu_i > 0$ $(i = 1, 2, \ldots, n)$ such that $|f_i(x) - f_i(y)| \leqslant \mu_i |x - y|$, for any $x, y \in R$, $i = 1, 2, \ldots, n$.

It is worth noting that system (1) has an equilibrium point and a continuous solution denoted simply $x(t) = (x_1(t), x_2(t), \ldots, x_n(t))^{\mathrm{T}}$ under assumptions (H1) and (H2) [5].