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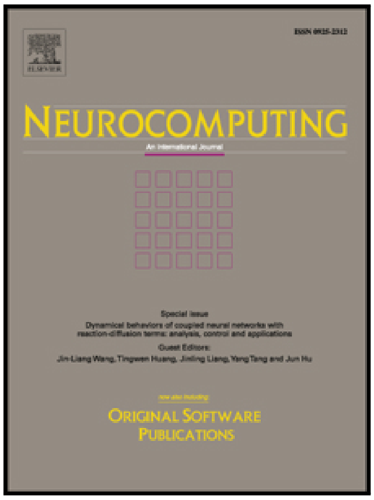

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Improved integral inequalities for stability analysis of delayed neural networks ☆

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Abstract

This paper is concerned with the exponential stability of delayed neural networks. Combined the Legendre polynomials with free-weighting matrices technique, an improved free-matrix-based single integral inequality is given, which includes the general single integral inequality and the free-matrix-based single integral inequality as special cases. Furthermore, a free-matrix-based double integral inequality which improves the existing results is derived. As applications of these novel free-matrix-based integral inequalities, several exponential stability criteria with less conservatism for the delayed neural networks are obtained. The effectiveness of our main results is illustrated by three numerical examples from the literatures.

Keywords: Neural network, exponential stability, integral inequality, free-weighting matrix

1. Introduction

Delayed neural networks have a strong application background in engineering due to the fact that time-delay is common and inevitable in nature, and often makes the networks oscillate or even causes instability. Stability analysis of delayed neural networks has drawn many scholars' attention[1-4]. Different from asymptotic stability of neural networks, the admissible maximal delay bound and the admissible rate of convergence are important indexes for the exponential stability criteria of neural networks.

In order to reduce the conservatism of stability criteria for the delayed neural networks, many scholars are devoted to constructing appropriate Lyapunov-Krasovskii functionals(LKFs) and developing effective methods to estimate their derivatives[5-10]. During the estimation of the derivatives of LKFs, the difficulty lies in handling the integral parts like $\int_a^b x^T(s)Rx(s)ds$ or double integral $\int_a^b \int_t^b x^T(s)Rx(s)dsdt$, which are usually treated by employing Jensen's inequality. In recent decades, many methods have been developed to reduce the conservatism caused by these kind of integral parts.

In 2013, Seuret and Gouaisbaut[11] provide an efficient stability condition in terms of Linear Matrix Inequalities(LMIs) by proposing a new Wirtinger-based integral inequality and extend some existing stability criteria based on the Jensen inequality. In 2015, Park et al.[12] give a novel class of integral inequalities for quadratic functions via some intermediate terms called auxiliary functions which improve the Wirtinger-based integral inequality. Based on these inequalities, some new stability criteria are presented for linear systems with time-varying delays by constructing some appropriate LKFs in [12]. Recently, based on the Legendre polynomials, Chen et al.[13] improve the auxiliary-functions-based integral inequality by giving two general integral inequalities. In fact, both methods in [12-13] involve with polynomials. Although the conservatism of inequalities in [12-13] decreases with increment of degree n of the polynomials, these inequalities will become more complex. Furthermore, the complexity of consequent stability conditions will increase with increment of the dimensions of LMIs. The main work of this paper focuses on deriving some effective stability criteria via establishing some more general integral inequalities under which the less conservative exponential stability of delayed neural networks is ensured.

Free-weighting matrix method is widely used to derive delay-dependent stability criteria for the delayed systems due to the fact that the model transformation and the technique of bounding cross terms can be avoided. Based on the free-weighting matrix method, Zeng et al.[6] present a new single integral inequality called a free-matrix-based single integral inequality , which includes the well-known Wirtinger-based single integral inequality as a special case. Moreover, a free-matrix-based double integral inequality is proposed in [14] which includes the Wirtinger-based double integral inequality as a special case. Since some free matrices are added into the inequality, more freedom can be provided in bounding the integral. This stimulates us to establish some more general integral inequalities based on the free-weighting matrix technical note.

Motivated by the discussion above, the free-matrix-based integral inequalities are introduced for stability analysis of delayed neural networks in this paper. Combined the Legendre polynomials with free-weighting matrices technical notes, some improved free-matrix-based single integral inequalities are given, which include the general single integral inequality in [13] and the free-matrix-based single integral inequality in [6] as special cases. Following the similar procedure, a new free-matrix-based double integral inequality is derived, which improves the free-matrix-based double integral inequality proposed in [14]. As an application of these novel inequalities, several less conservative exponential stability criteria for the delayed neural networks are obtained. The effectiveness of the

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