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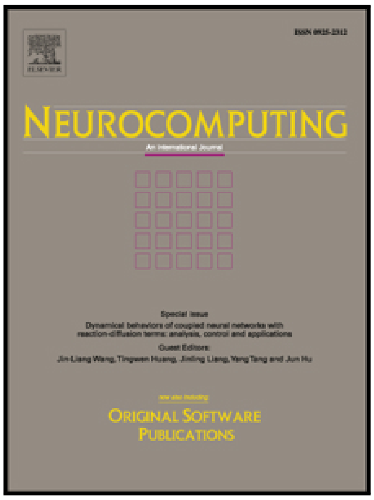

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On designing state estimators for discrete-time recurrent neural networks with interval-like time-varying delays ☆

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Abstract

This paper deals with designing state estimators for a class of discrete-time recurrent neural networks with interval-like time-varying delays. Based on a delay bi-decomposition idea, a new Lyapunov functional is introduced, which takes into account more information on the interval-like time-varying delay and the neuronal activation function. This Lyapunov functional, together with an improved reciprocally convex inequality, is employed to derive a sufficient condition to design suitable Luenberger-type estimators by solutions to linear matrix inequalities. An example is taken to show the effectiveness of the proposed method.

Keywords: Discrete-time neural networks, Luenberger-type estimator, time-varying delay, reciprocally convex inequality.

1. Introduction

The last two decades have witnessed successful applications of recurrent neural networks (RNNs) to a number of information processing systems, including parallel computation, learning ability and model processing etc. [1]. In the implementation of a real RNN, time-delays commonly occur due to the finite switching speed of amplifiers and the inherent communication time of neurons [2–4]. Time-delays are often a source of oscillation, divergence, and instability of practical engineering systems [5–7]. Therefore, delayed neural networks have become a hot research topic and some important issues, such as stability, passivity and dissipativity are addressed for various dynamic neural networks with time-delays, see, e.g. [8–12].

State estimation on delayed neural networks is an important issue from both theoretical and practical points of view, due to the fact that the neuron states in relatively large scale neural networks are not completely available for practical applications. The state estimation problem of a delayed neural network aims to design an estimator based on its output measurements to estimate the neuron states. This problem is first considered in [3]. However, the obtained condition is delay-independent, which is somewhat conservative, especially for a neural network with a small time-delay. In [13], a free-weighted matrix approach is introduced to derive some delay-dependent condition, leading to the notion of delay-dependent state estimation. Since then, delay-dependent state estimation has attracted more attention than the delay-independent one, aiming to seek less conservative sufficient conditions on the existence of proper state estimators. By employing a descriptor model transformation approach, a free-weighted matrix approach and an integral inequality approach, delay-dependent state estimation for neural networks with time-varying delays is extensively investigated, and a number of less conservative criteria for the estimator design are reported in the literature, see, e.g. [14–17]. Nevertheless, all the above-mentioned results are based on neural networks in the continuous-time domain, while relatively few results on neural networks in the discrete-time domain. Although the delay-dependent state estimation issue on discrete-time neural networks with time-varying delays is addressed in [18–20], there is still much room for improvement.

It should be noted that most results on delay-dependent state estimation are based on the Lyapunov functional approach, in which the chosen Lyapunov functional usually includes a double and/or a triple integral/summation term [21]. Once the increment of the Lyapunov functional is calculated, the second step comes from the inequalities to be used to derive some sufficient condition which can be verified through solving a tractable numerical optimization problem [7, 22]. In this situation, and in the discrete-time domain, those cross terms appearing in the forward difference of the Lyapunov functional are bounded using some summation inequalities. In the recent years, some novel summation inequalities as a discrete counterpart of the Wirtinger-based integral inequality are proposed to analysis the stability of discrete time-delay systems [23, 24]. For the discrete-time neural networks with interval-like time-varying delay, a reciprocally convex combination should be dealt with during estimating the forward difference of the Lyapunov functional. The lower bound for such a combination is essential to derive less conservative conditions. Recently, an improved reciprocally convex inequality is reported [25], which enable us to develop a less conservative result to design suitable state estimators for the discrete-time neural networks with interval-like time-varying delays.

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