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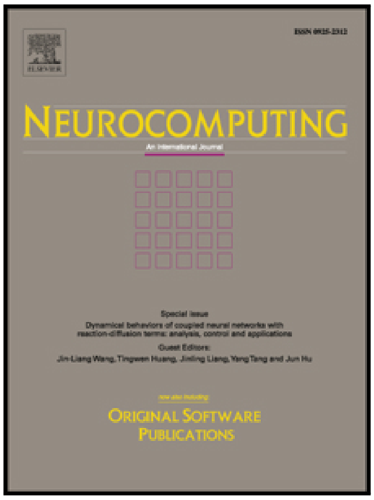

State Estimation for Neural Networks with Jumping Interval Weight Matrices and Transmission delays

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***Abstract*—This work addresses the state estimation problem for the neural networks possessing Markovian jump weight matrices and transmission delays. Markovian jump interval matrices are introduced to model the uncertainty of the connections among neurons, and the polytopic model is used to describe the uncertainty of the Markov transition matrix. The mode-dependent transmission delays are introduced to describe an unideal communication channel. A sufficient condition of the stochastic stability and the strict-(Q,S,R) dissipative performance is derived for the augmented system. Mode-dependent estimator gains are then designed. At last, an example is employed to illustrate the obtained results.**

***Index Terms*—Neural networks, state estimation, uncertain weight matrix, transmission delays.**

I. Introduction

The neural networks consist of numerous neurons, and each neuron possesses a activation function and the output information of this function exchanges among the neurons via the connection weight matrix. The neural networks have been considered by many researchers because of their applications in a variety of areas [1]–[7]. It is well-known that the parameters (including the weight matrix) of the neural networks are frequently influenced by the environment factors (i.e., temperature, humidity, and so on). Therefore, the robustness analysis for the neural networks becomes a hotspot [8]. In [9], the norm-bounded model was introduced to describe the uncertainty of the neural networks with a stochastic term and time delays. In [10], the polytopic model was employed to deal with the parameters with a uncertainty. In [11], the interval matrix method was considered to handle the uncertainty of the neural networks. With the development of the neural networks, how to further study the uncertainty of the neural networks becomes an important problem.

Communication constraints induced problems, including quantization error [12]–[14], transmission delays [15], channel fading [16], packet dropouts [17], and so on, are unavoidable in networked control systems (NCSs), and they have been studied by a number of researchers [18]–[21]. For transmission delays, some methods have been proposed to handle different delay models. In [22], the lifting technique was used to deal with Markov-based transmission delays for discrete-time systems, and the necessary and sufficient conditions of the stochastic stability for the closed-loop system were proposed. In [23], the Lyapunov-Krasovskii method was considered to study the randomly occurred transmission delays. Note that Jensen's inequality and the free weighting matrix method are always employed to handle the delay terms in the Lyapunov-Krasovskii function. For neural networks, the measurements are frequently transmitted via the wireless networks. Thus it is important to study the neural networks with transmission delays.

State estimation is indispensable for the neural networks, because it is too difficult to obtain their inner states directly. So far many meaningful works concerning how to use the available measurements to estimate the states of the neural networks have been published [24], [25]. In [26], the robust estimator was designed for the neural networks possessing a norm bounded uncertainty and time delays. In [27], the state estimator was designed for the neural networks, whose measurements are transmitted over the imperfect multiple communication channels. In [28], the event-trigger based estimator, which can simultaneously deal with randomly occurred packet droppts, sensor saturation, and quantization error, was obtained. However, the robust estimator designing for the neural networks based on the imperfect measurements still needs more attention.

This work focuses on the state estimation for the neural networks with uncertain weight matrices and transmission delays. The mode-dependent state estimators are designed to guarantee that the augmented system is stochastically stable with strict-(Q, S, R) dissipativity, then the results are illustrated using a numerical example. The contributions concerning this work are as follows.

- The environment factors (i.e., temperature, humidity, noises, etc.) influence the parameters of the neural networks. Thus the interval matrices with Markov jump properties are introduced to describe the uncertain weight matrices, which is more general than the exiting one [11]. A polytopic model is employed to overcome the difficulty that the accurate transition matrix of a Markov chain is hard to be obtained accurately.
- The environment factors also impact the communication channels. Thus the mode-dependent transmission delays are addressed.

In this work, the spaces of the square summable infinite sequences, the n-dimension real vectors, and the $m \times n$ real matrices are denoted by $l_2[0, +\infty)$, $\mathbb{R}^n$, and $\mathbb{R}^{m\times n}$, respectively. The transposition of matrix M is represented

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