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Exponential stability analysis for discrete-time impulsive delay neural networks with and without uncertainty

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Abstract

The purpose of this paper is to investigate the exponential stability for discrete-time impulsive delay neural networks and the robust exponential stability for discrete-time impulsive delay neural networks with uncertainty. By using Lyapunov functionals, first some new results on exponential stability for neural networks without uncertainty are presented, and then some results on robust exponential stability for neural networks with uncertainty are provided. Both the stability results that impulses act as perturbations and the stability results that impulses act as stabilizer are given. The obtained results have the virtue that they can deal with neural networks with any fixed time delay. Moreover, the impulsive interval is larger than 2 or the time delay is not needed in the main results. Some examples together with their simulations are also presented to show the effectiveness and the advantage of the obtained results.

1. Introduction

Over the past few decades, a number of results have been obtained for systems with impulse effect since impulsive systems can provide a natural framework for the modeling of many real world phenomena (see [1–30] and the references therein).

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On the other hand, time delay is unavoidable in many evolution processes (see, for instance, [4–9, 13–36]) and it is the inherent feature of many physical processes, is the big source of instability and poor performance.

In recent years, neural networks have been intensively studied due to their potential applications in different fields such as signal processing, robotics, associate memory and pattern recognition (see [5–8, 12–19, 27–36] and the references therein). It is known that signal transmission delays always exist in neural networks. Meanwhile, the state of electronic networks may experience abrupt change at certain moment of time, i.e., the impulse effect always exist in neural networks. Thus it is necessary to study neural networks with time delays and impulses.

It is worth mentioning that most of the existing results pertain to the stability analysis for continuous-time impulsive delay neural networks. However, many phenomena are described by discrete-time systems and in the fields of engineering especially the numerical simulation, the models always are discrete-time systems (see, for instance, [10–22, 31–33]). Generally speaking, the discrete-time neural network may but not always preserve the dynamics of its continuous version. In practice, the dynamics of discrete-time neural networks may be quite different from those of continuous-time ones.

But the theory of discrete-time impulsive delay neural networks has not been fully developed yet (see, for instance, [13–19]). The existence and global exponential stability of periodic solution for a class of cellular neural networks difference equation with delays and impulses have been considered in [13]. The discrete-time fuzzy cellular neural networks with delays and impulses have been studied in [14], the impulses act as perturbations in the main results of this paper. By using Razumikhin technique, the impulsive stabilization results for neural network without uncertainty have been given in [15]. Both the destabilizing and stabilizing effects of impulses are revealed in [16] for neural networks without uncertainty. The impulses act as perturbations in [17–19], i.e., the original neural network without impulses is stable.

Furthermore, the stability of a neural network may often be destroyed by its unavoidable uncertainties. Thus, the robust stability analysis of neural networks with uncertainty is necessary. However, to the best of the author's knowledge, there are rare results about discrete-time impulsive delay neural networks with uncertainties.

Motivated by the above discussions, in the present paper, we will first consider the exponential stability of discrete-time impulsive delay neural networks, then we will consider the robust exponential stability of discrete-time impulsive delay neural networks with uncertainties. The Lyapunov functionals will be used to obtain some new results. The results we obtained show that the impulse-free neural network which is not (robustly) stable can be (robustly) exponentially stable under certain impulses. We also obtain the stability criteria that show when the impulse-free neural network is (robustly) stable then the stability property of the neural network with impulses can be retained if the time interval between the nearest two impulses is large enough.

This paper is organized as follows. In Section 2, we introduce some basic definitions and notations. In Section 3, first we get some exponential stability criteria for discrete-time impulsive delay neural networks, then we give the robust exponential stability criteria for discrete-time impulsive delay neural networks with parametric uncertainties. Some examples together with their simulations will also be presented to illustrate the effectiveness and the advantage of the proposed results. Finally, concluding remarks are given in Section 4.