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WEIGHTED PSEUDO ALMOST-PERIODIC SOLUTIONS OF SHUNTING INHIBITORY CELLULAR NEURAL NETWORKS WITH MIXED DELAYS*

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Abstract In this paper, we prove the existence and the global exponential stability of the unique weighted pseudo almost-periodic solution of shunting inhibitory cellular neural networks with mixed time-varying delays comprising different discrete and distributed time delays. Some sufficient conditions are given for the existence and the global exponential stability of the weighted pseudo almost-periodic solution by employing fixed point theorem and differential inequality techniques. The results of this paper complement the previously known ones. Finally, an illustrative example is given to demonstrate the effectiveness of our results.

Key words weighted pseudo almost-periodic solution; shunting inhibitory cellular neural networks; mixed delays; global exponential stability

2010 MR Subject Classification 34K05; 92B20; 34C27; 34D20; 34K40; 47H10

1 Introduction

In the past few decades, the neural networks were studied extensively. There were many research results about the existence, uniqueness and stability of almost periodic, asymptotically almost periodic and pseudo-almost periodic solutions of neural network due to their potential application in classification, associative memory, parallel computation and other fields as mentioned in (see [4–9, 11–14, 16–20, 23, 26, 27, 37]).

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As well known, both in biological and man-made neural networks, delays are inevitable, due to various reasons. For instance, time delays can be caused by the finite switching speed of amplifier circuits in neural networks. Time delays in the neural networks make the dynamic behaviors become more complex, and may destabilize the stable equilibria and admit oscillations, bifurcation and chaos. Such application heavily depend on their dynamics, hence we investigate the dynamical behaviour of the neural networks. Thus, it is very important to study the dynamics of neural networks delay.

Cellular neural networks (CNNs) showed great potential as information-processing systems. Recently, many authors paid much attention to the research on the theory and application of the CNNs. The Shunting Inhibitory Artificial Neural Networks (SIANNs) are a new class of CNNs and are biologically inspired networks in which the synaptic interactions among neurons are mediated via a nonlinear mechanism called shunting inhibition, which equips neurons with a gain control mechanism that allows them to operate as adaptive nonlinear filters. Since Bouzerdout and Pinter in (see [1]) described SICNNs as a new cellular neural networks (CNNs), SICNNs were extensively applied in psychophysics, speech, perception, robotics, adaptive pattern recognition, vision, and image processing. In this paper, we consider the following models for shunting inhibitory cellular neural networks with mixed delays as follows

$$\begin{aligned} x'_{ij}(t) = &-a_{ij}(t)x_{ij}(t) - \sum_{C_{kl}\in N_q(i,j)} B^{kl}_{ij}(t)g(x_{kl}(t))x_{ij}(t) \\ &- \sum_{C_{kl}\in N_p(i,j)} D^{kl}_{ij}(t)h(x_{kl}(t-\tau(t)))x_{ij}(t) \\ &- \sum_{C_{kl}\in N_r(i,j)} C^{kl}_{ij}(t)\int_0^{+\infty} K_{ij}(u)f(x_{kl}(t-u))\mathrm{d}u x_{ij}(t) \\ &+L_{ij}(t),\ 1\le i\le m,\ 1\le j\le n. \end{aligned} \tag{1.1}$$

The mixed delays include time-varying delays and unbounded distributed delays. Model (1.1) was the subject of intensive analysis by numerous authors in recent years. In particular, there were extensive results on the problems of the exponential convergence of solution of SICNNs [21], the existence and stability of almost periodic and positive almost periodic solutions of SICNNs (see [2, 3, 10, 22, 24, 25, 33–35]) and the existence and stability of pseudo almost-periodic solutions of SICNNs (see [15, 31]). Here we introduce a new class of functions called weighted pseudo-almost periodic functions (see [28–30, 32]) generalized pseudo-almost periodic and almost periodic functions. The main idea is to put a weight (a locally integrable function on all $\mathbb{R}$), on ergodic component appearing in [2, 31] and obtain the weight space. In this way, a pseudo-almost-periodic function with weight appear as a perturbation of an almost-periodic function by an ergodic component of the weight space. Since the space of weighted pseudo almost-periodic functions contains strictly the space of pseudo almost-periodic, almost-periodic and periodic functions, the criteria obtained in this paper extend and improve the results given by Anping Chen and Jinde Cao in [2].

The rest of this paper is organized as follows. In Section 2, we will recall the basic properties of the weighted pseudo almost-periodic functions. In Section 3, we will introduce some necessary notations, definitions, and preliminaries that will be used later. The existence and the uniqueness of weighted pseudo almost-periodic solutions of (1.1) in the suitable convex set are

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