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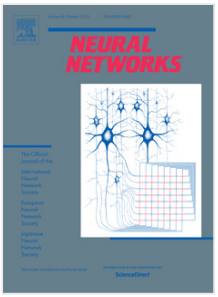

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A new class of multi-stable neural networks: stability analysis and learning process

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Abstract: Recently, multi-stable Neural Networks (NN) with exponential number of attractors have been presented and analyzed theoretically; however, the learning process of the parameters of these systems while considering stability conditions and specifications of real world problems has not been studied. In this paper, a new class of multi-stable NNs using sinusoidal dynamics with exponential number of attractors is introduced. The sufficient conditions for multi-stability of the proposed system is posed using Lyapunov theorem. In comparison to the other methods in this class of multi-stable NNs, the proposed method is used as a classifier by applying a learning process with respect to the topological information of data and conditions of Lyapunov multi-stability. The proposed NN is applied on both synthetic and real world datasets with an accuracy comparable to classical classifiers.

Keywords: multi-stable neural network; exponential number of attractors; Lyapunov stability; classification, sinusoidal dynamic.

1. Introduction

Dynamical Neural Networks (NN) are powerful methods which are applied in system identification and modeling nonlinear dynamical systems (Nørgaard, 2000; Janczak, 2005; Liu, 2001), classification of time series (Ao, 2010; Hu & Hwang, 2010) and pattern recognition using memories (Zurada, 1992; Perfetti & Ricci, 2008; Wang et al., 1990; Shen & Cruz, 2005; Chartier & Boukadoum, 2006; Sudo et al., 2009). Within neurobiological aspect, these methods are important to emulate and explain different biological behaviors includes information storage and recall (Zeng and Zheng, 2012).

In real world recognition problems, by means of neural networks, in which the number of classes is high (e.g. in data mining (Lin et al., 2008), object recognition (Sonka et al. 2014), etc.), a new framework may be useful or even necessary. Recently, multi-stable neural networks with exponential number of attractors have received considerable attention. By applying one step piecewise linear activation function in *n*-neuron dynamical NN, coexistence of 2^n locally exponentially stable equilibrium points under studied conditions is shown (Zeng et al., 2004; Zeng & Wang, 2006). In (Lili et al., 2010), a class of *r*-level piecewise linear nondecreasing activation functions is used to increase the storage capacity of multi-stable NNs. The storage capacity of dynamical NNs increases in (Zeng & Zheng, 2012) by applying time-varying delays as well as activation functions with concave-convex characteristics.

After proposing the concept of μ-stability which concerns NNs with unbounded time-varying delays (Chen & Wang, 2007a; Chen & Wang, 2007b), multiple μ-stable NNs with unbounded time-varying delays is presented in (Wang & Chen, 2014). Other studies on the subject of multi-stable NNs include, but not limited to, bidirectional associative memories with exponential number of attractors (Du & Xu, 2014), analyzing the effect of disturbed delays (Nie & Cao, 2009), conditions of existence of limit cycle (Chenga et al., 2007), applying different types of activation functions includes Mexican-hat-type (Nie et al., 2014) and real-imaginary-type (Huang et al., 2014).