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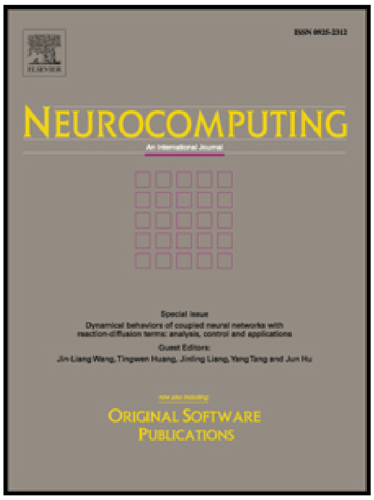

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Stabilization of Desired Periodic Orbits in Dynamic Binary Neural Networks

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Abstract

A dynamic binary neural network is a simple two-layer network with a delayed feedback and is able to generate various binary periodic orbits. The network is characterized by the signum activation function, ternary connection parameters, and integer threshold parameters. The ternary connection brings benefits to network hardware and to computation costs in numerical analysis. In order to stabilize a desired binary periodic orbit, a simple evolutionary algorithm is presented. The algorithm uses individuals corresponding to the ternary connection parameters and one zero element is inserted into each individual. Each individual is evaluated by two feature quantities that characterize the stability of the periodic orbit. The zero-insertion is able to reinforce the stability and is convenient to reduce power consumption in a hardware. Applying the algorithm to a class of periodic orbits, the stabilization capability is investigated. Some of the periodic orbits are applicable to control signals of switching power converters.

Keywords: Dynamic binary neural network, Periodic orbit, Stability, Stabilization.

1. Introduction

Applying a delayed feedback to the two-layer neural network, the dynamic binary neural network (DBNN) is constructed [1]-[3]. The DBNN is characterized by the signum activation function [4]-[7], ternary connection parameters and integer threshold parameters. Comparing an input with the threshold, the signum activation function outputs a binary value. The ternary connection is convenient in a hardware implementation by digital circuits as suggested in [8]. Depending on the parameters and initial condition, the DBNN can generate various binary periodic orbits (BPOs). The dynamics of the DBNN is integrated into the digital return map (Dmap) on a set of points [3]. The Dmap can be regarded as a digital version of an analog return map such as the logistic map [9]. The Dmap is useful in visualization/consideration of the dynamics. Since the state variables are binary and connection parameters are ternary, the dynamics of the Dmap/DBNN can be calculated by the integer arithmetic and the computation costs can be reduced in numerical analysis [3].

The DBNN is a kind of digital dynamical systems where time, state, and parameters are all discrete [10]-[15]. The digital dynamical systems have been applied to engineering systems. For example, the cellular automata can generate various spatio-temporal patterns and have been applied to signal processing [10]-[12]. The digital spiking neurons can generate various spike-trains and have been applied to ultra-wide-band communications [13] [14]. The BPOs of the DBNN have been applied to control signals of switching power converters [3]. That is, study of such systems is significant in both fundamental and application viewpoints.

This paper studies stability and stabilization of a desired BPO of the DBNNs. It goes without saying that the stability is an important concept in analysis of nonlinear phenomena and corresponds to robust/reliable system operation in engineering applications. Although there exist several methods to store periodic orbits into neural networks [15]-[18], stabilization of the stored periodic orbits has not been considered sufficiently.

First, using the Dmap, we define two kinds of stabilities of a BPO: global stability such that all the initial points fall eventually into the BPO and uniform stability such that all the initial points fall uniformly into the BPO. The uniform stability is a special case of the global stability. In analog dynamical systems, definition of stability has been studied sufficiently [9]. However, the definition cannot be applied to digital dynamical systems. Because the "analog" stability is based on mapping from a set of real numbers whereas the "digital" stability is based on mapping from a set of binary numbers. Hence we have defined the stabilities of the BPO.

Second, we present two feature quantities α and β that characterize the global and uniform stabilities, respectively. The feature quantities are used to evaluate the stabilities of a desired BPO. The evaluation is indispensable in the stabilization, however, feature quantities for the evaluation have not been presented in previous works.

Third, we present a simple evolutionary algorithm (SES) for uniform stabilization of a desired BPO. The SES uses individuals corresponding to a set of ternary connection parameters and one zero element is inserted into each individual. The zero-insertion corresponds to wire cutting in a hardware that is convenient to reduce power consumption. For the storage of a BPO, we have a simple method based on the correlation learning (CL-based learning, [1] [18]). If the CL-based learning can store a desired BPO into the DBNN, the set of connection parameters is used as an initial individual. The quantity β is used

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