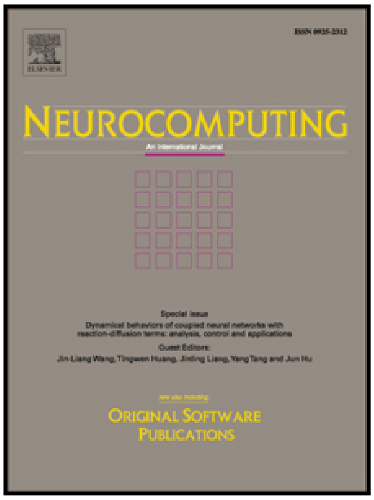
Communicated by Dr. A. Belatreche

Accepted Manuscript



Efficient training of supervised spiking neural networks via the normalized perceptron based learning rule

Xiurui Xie, Hong Qu, Guisong Liu, Malu Zhang

PII: S0925-2312(17)30309-0
DOI: 10.1016/j.neucom.2017.01.086
Reference: NEUCOM 18105

To appear in: *Neurocomputing*

Received date: 4 January 2016
Revised date: 8 November 2016
Accepted date: 20 January 2017

Efficient training of supervised spiking neural networks via the normalized perceptron based learning rule

Xiurui Xie, Hong Qu*, Guisong Liu, Malu Zhang

School of Computer Science and Engineering, University of Electronic Science and Technology of China, Chengdu 610054, P. R. China

Abstract

The spiking neural networks (SNNs) are the third generation of artificial neural networks, which have made great achievements in the field of pattern recognition. However, the existing supervised training methods of SNNs are not efficient enough to meet the real-time requirement in most cases. To address this issue, the normalized perceptron based learning rule (NPBLR) is proposed in this paper for the supervised training of the multi-layer SNNs. Different from traditional methods, our algorithm only trains the selected misclassified time points and the target ones, employing the perceptron based neuron. Furthermore, the weight modification in our algorithm is normalized by a voltage based function, which is more efficient than the traditional time based method because the firing time is calculated by the voltage value. Superior to the traditional multi-layer algorithm ignoring the time accumulation of spikes, our algorithm defines the spiking activity of the postsynaptic neuron as the rate accumulation function of all presynaptic neurons in a specific time-frame. By these strategies, our algorithm overcomes some difficulties in the training of SNNs, e.g., the inefficient and no-fire problems. Comprehensive simulations are conducted both in single and multi-layer networks to investigate the learning performance of our algorithm, whose results demonstrate that our algorithm possesses higher learning efficiency and stronger parameter robustness than traditional algorithms.

Keywords: Spiking neural networks, Temporal encoding mechanism, Supervised learning, Perceptron based learning rule

1. Introduction

As the methods with the highest level of realism in a neural simulation at present [1][2], the SNNs were introduced as the third generation of neural networks and have achieved great success in various artificial intelligence tasks [3]–[15]. Recent studies prove that the spiking neural networks employing the temporal encoding mechanism possess more powerful computational capability and more biological evidences than networks with other encoding schemes [16]–[18]. Additionally, the electrophysiology experiments on cat's visual system and monkey striate cortex reveal that the information in biological neurons is processed hierarchically [19][20]. Therefore, training the hierarchical spiking neural network with temporal encoding mechanism is by far the closest way to the biological system.

To complete the supervised training tasks of SNNs, various training algorithms have been proposed, which can broadly be divided into two classes: the training algorithm for single layer and that for multiple layers.

The single layer training algorithms are introduced based on the gradient decent rule or learning windows. By the gradient decent rule, the Tempotron [21] is a classical algorithm employing the distance of the output voltage and the firing threshold as the cost function. It achieves the training process efficiently, but it can only complete binary classification tasks. After which, the Chronotron E-learning [22] and SPAN (Spike Pattern Association Neuron) algorithm [23] try to minimize the distance between the target and actual output spike trains by the gradient descent rule. The distance in Chronotron E-learning is defined by the Victor and Purpura (VP) metric [24], and in the SPAN rule is defined by the Van Rossum similar metric [25]. These algorithms can complete multiple classification tasks robustly. However, they are time consuming compared with the Temporal method.

To improve the training efficiency, algorithms instructing training by learning windows, such as the Spike-Timing-Dependent Plasticity (STDP) window [26] have been proposed. In this respect, the remote supervised learning method (ReSuMe) is a classical one. It applies both the STDP and the anti-STDP learning window to drive training [27]. To enhance the learning performance of the ReSuMe, the delay learning remote supervised method (DL-ReSuMe) [28] is proposed. It combines the delay shifting with the traditional ReSuMe method to achieve a good training performance. The ReSuMe and its variation are trained by the instruction of the supervised neuron, which are more efficient than the traditional methods employing the gradient decent rule. However, they are still not efficient enough because the information in them is processed serially on time.

To solve this problem and further improve the training effi-

*Corresponding author
Email: hongqu@uestc.edu.cn (Hong Qu)
This work was supported in part by the National Science Foundation of China under Grants 61273308 and 61573081.