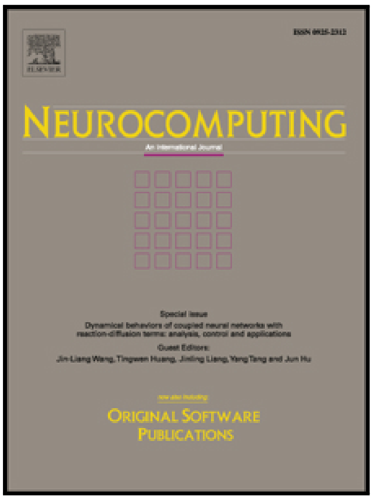
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Improving Efficiency in Sparse Learning with the Feedforward Inhibitory Motif

Zihan Xu[a], Steven Skorheim[b], Ming Tu[c], Visar Berisha[c], Shimeng Yu[a], Jae-sun Seo[a], Maxim Bazhenov[d], Yu Cao[a,*]

[a]School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, Arizona, United States
[b]Department of Cell Biology and Neuroscience, University of California Riverside, Riverside, California, United States
[c]Department of Speech and Hearing Science, Arizona State University, Tempe, Arizona, United States
[d]School of Medicine, University of California San Diego, La Jolla, California, United States

Abstract

Neuro-inspired computing has made significant progress in recent years. However, its computation efficiency and hardware cost still lag behind the biological nervous system, especially during the training stage. This work targets to understand this gap from a neural motif perspective, particularly the feedforward inhibitory motif. Such a motif has been found in many cortical systems, presenting a vital role in sparse learning. This work first establishes a neural network model that emulates the insect's olfactory system, and then systematically studies various effects of the feedforward inhibitory motif. The performance and efficiency of the neural network models are evaluated through the handwritten digits recognition task, with and without the feedforward inhibitory motif. As demonstrated in the results, the utilization of the feedforward inhibitory motif is able to reduce the network size by >3X at the same accuracy of 95% in handwritten digits recognition. Further simulation experiments reveal that the feedforward inhibition not only dynamically regulates the firing rate of excitatory neurons, promotes and stabilizes the sparsity, but also provides a coarse categorization of the inputs, which improves the final accuracy with a smaller, cascade structure. These results differentiate the feedforward inhibition path from previous understanding of the feedback inhibition, illustrating its functional importance for high computation and structure efficiency.

Keywords

Neural Motif; Feedforward Inhibition; Sparse Learning; Spiking Neural Network; Hebbian Learning; Handwritten Recognition

1. Introduction

Neuro-inspired computing, including learning and inference, has made significant progress in recent years and will fundamentally alter the way individuals and organizations live, work and interact with each other [1-4]. Machine learning and deep learning algorithms have been successfully applied to many data processing and analysis tasks, including feature extraction from images and videos [5-8], image segmentation [9], and big multimedia analysis [10]. While many previous efforts have been made to improve the optimization algorithms for artificial neural networks [11-13], the computational complexity of artificial neural networks still challenges the state-of-the-art hardware platforms, especially mobile applications that are tightly constrained by energy efficiency and hardware size [14]. In contrast, animal brains, as a natural system for information processing, exhibit extraordinary features of ultra-high energy efficiency [15], low hardware overhead, and high accuracy in perceptual and learning tasks. For instance, the olfactory system in fruit flies only contains about 5000 neurons [16]; after a very small number of stimulus presentations, it is capable to detect tens of thousands of odors at very high accuracy. The locust antennal lobe consists of ~830 excitatory projection neurons and 300 inhibitory local neurons [17], achieving sparse odor representation that is specific over thousand-fold changes in odor concentration [18]. Indeed, the efficiency of information processing by the sensory and cortical systems is vitally important to animal survival in nature.

Many efforts have been made to capture the advantages of the nervous systems by creating computational models, with biologically plausible learning rules [19-25]. Among neurons, the two basic forms of data transmission are excitation and inhibition. Excitation has been extensively shown to be the primary path of data processing and feature extraction. Neural network models with excitation only can be trained to recognize images, differentiate objects, and categorize input data [21]. In addition to excitation, the inhibition provided by interneurons is indispensable to learning and behavioral adaptation, as observed in a variety of species [26]. Even though the