On Temporal Summation in Chaotic Neural Network with Incremental Learning

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ABSTRACT

The incremental learning is a method to compose an associate memory using a chaotic neural network and provides larger capacity than correlative learning in compensation for a large amount of computation. A chaotic neuron has spatiotemporal summation in it and the temporal summation makes the learning stable to input noise. When there is no noise in input, the neuron may not need temporal summation. In this paper, to reduce the computations, a simplified network without temporal summation is introduced and investigated through the computer simulations comparing with the network as in the past, which is called here the usual network. It turns out that the simplified network has the same capacity in comparison with the usual network and can learn faster than the usual one, but that the simplified network loses the learning ability in noisy inputs. To improve this ability, the parameters in the chaotic neural network are adjusted.

Keywords: Associative Memory, Chaotic Neural Network, Incremental Learning, Simplification, Temporal Summation

INTRODUCTION

Neurobiological studies show evidences of chaotic behavior in animal and human brains both in neuron and global brain activities (Freeman & Barrie, 1994; Guevara, Glass, Mackey & Shrier, 1983; Freeman, 1987; Babloyantz & Lourenco, 1996). Also, neural network studies suggest that the presence of chaos plays a central role in memory storage and retrieval (Freeman & Barrie, 1994; Lourenco & Babloyantz, 1996; Tsuda, 1996; Crook, Dobbyn & Olde, 2000). The incremental learning proposed by the authors is highly superior to the auto-correlative learning in the ability of pattern memorization (Asakawa, Deguchi & Ishii, 2001; Deguchi & Ishii, 2004; Deguchi, Fukuta & Ishii, 2013; Deguchi, Matsuo, Kimura & Ishii, 2009-11; Deguchi, Takahashi & Ishii, 2014).

The idea of the incremental learning is from the automatic learning (Watanabe, Aihara & Kondo, 1994). In the incremental learning, the network keeps receiving the external inputs. If the network has already known an input pattern, it recalls the pattern. Otherwise, each neuron in it learns the pattern gradually. Therefore, the

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weak point of the learning is computational complexity. The network takes steps to learn input patterns.

The neurons used in this learning are the chaotic neurons, and their network is the chaotic neural network, which was developed by Aihara (Aihara, Tanabe & Toyoda, 1990).

A chaotic neuron has spatiotemporal summation in it and the temporal summation makes the learning possible with noisy inputs. But, when inputs don’t include any noises, the neuron can be simpler without the temporal summation. This simplification reduces the computational complexity.

In this paper, first, we explain the chaotic neural networks and the incremental learning, then simplify the network by eliminating the temporal summation from the chaotic neurons and examine the simplified network comparing with the usual one.

**CHAOTIC NEURAL NETWORKS AND INCREMENTAL LEARNING**

The incremental learning was developed by using the chaotic neurons. The chaotic neurons and the chaotic neural networks were proposed by Aihara (Aihara, Tanabe & Toyoda, 1990).

We presented the incremental learning that provides an associative memory (Asakawa, Deguchi & Ishii, 2001; Deguchi, Fukuta & Ishii, 2013; Deguchi, Matsuo, Kimura & Ishii, 2009-11; Deguchi, Takahashi & Ishii, 2014). The network type is an interconnected network, in which each neuron receives one external input, and is defined as follows (Aihara, Tanabe & Toyoda, 1990):

\[
x_i(t + 1) = f(x_i(t + 1) + \eta_i(t + 1) + \zeta_i(t + 1),
\]

\[
\xi_i(t + 1) = k_s \xi_i(t) + \nu A_i(t),
\]

\[
\eta_i(t + 1) = k_m \eta_i(t) + \sum_{j=1}^{n} w_{ij} x_j(t),
\]

\[
\zeta_i(t + 1) = k_r \zeta_i(t) - \alpha \varepsilon (x_i(t) - \theta_i(1 - k_r),
\]

where \(x_i(t + 1)\) is the output of the \(i\)-th neuron at time \(t + 1\), \(f\) is the output sigmoid function described below in (5), \(k_s, k_m, k_r\) are the time decay constants, \(A_i(t)\) is the input to the \(i\)-th neuron at time \(t\), \(\nu\) is the weight for external inputs, \(n\) is the size—the number of the neurons in the network, \(w_{ij}\) is the connection weight from the \(j\)-th neuron to the \(i\)-th neuron, and \(\alpha\) is the parameter that specifies the relation between the neuron output and the refractoriness.

\[
f(x) = \frac{2}{1 + \exp \left( \frac{-x}{\varepsilon} \right)} - 1,
\]

In the incremental learning, each pattern is inputted to the network for some fixed steps before moving to the next. In this paper, this term is called “input period”, and “one set” is defined as a period for which all the patterns are inputted. The patterns are inputted repeatedly for some fixed sets.

During the learning, a neuron which satisfies the condition of (6) changes the connection weights as in (7) (Asakawa, Deguchi & Ishii, 2001; Deguchi, Fukuta & Ishii, 2013; Deguchi, Matsuo, Kimura, & Ishii, 2009-11; Deguchi, Takahashi, & Ishii, 2014).

\[
\xi_i(t)(x_i(t) + \eta_i(t) + \zeta_i(t)< 0,
\]

\[
w_{ij} = \begin{cases} w_{ij} + \Delta w, & \xi_i(t) x_j(t) > 0 \\ w_{ij} - \Delta w, & \xi_i(t) x_j(t) \leq 0 (i \neq j), \end{cases}
\]

where \(\Delta w\) is the learning parameter.

If the network has learned a currently inputted pattern, the mutual interaction \(\eta_i(t)\) and the external input \(\xi_i(t)\) are both positive or both negative at all the neurons. This means...
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