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Multi-Layer Perceptron Introducing Glial Pulse Propagating to Two Directions

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1. Introduction

The glia is one of nervous cells in a brain. Recently, the glia attracts researchers' attentions, because this cell can transmit signals each other. The glias have some ions' channels, thus the glias possess important relationship with neurons for the brain works [1].

In the previous study, we proposed the pulse glial chain which was inspired from the features of the glias. The glia generates a pulse by a connecting neuron and the pulse excites the glias on one side.

In this study, we propose the Multi-Layer Perceptron (MLP) introducing glial pulse propagating to two directions. We broaden the definition of the pulse glial chain to the glial pulse propagating to two directions. In the proposed MLP, all glias are excited by the connecting neurons' outputs and affects its neighborhood glias on both sides. We confirm that the proposed MLP has better learning performance than the conventional methods by the simulation.

2. Proposed method

The glial pulse propagating to two directions is defined by Eq. (1).

$$\psi_i(t+1) = \begin{cases} 1, & \{(\theta_n < y_i \cup \psi_{i+1,i-1}(t - i*D) = 1) \\ & \qquad \cap (\theta_g > \psi_i(t))\} \\ \gamma\psi_i(t), & else, \end{cases} \quad (1)$$

where ψ is an output of a glia, γ is an attenuated parameter, y is an output of a connecting neuron, θ_n is a glia threshold of excitation, θ_g is a period of inactivity, and D is a delay time of a glia's effect. In the proposed MLP, the glias are excited by the connecting neuron or glias on both side. After that, the exciting glias generate outputs pulse.

We connect glial pulse propagating to two directions to the thresholds of hidden layer's neurons in the MLP. Because, the biological glia can change the neuron membrane potentials. The neuron updating rule of the hidden layer's is given by Eq. (2).

$$y_i(t) = \sum_{j=1}^{N}(w_{ij}x_j(t) - \theta + \psi_i(t)) \quad (2)$$

where y is an output, w is a weight parameter of neurons and x is an input. In general, the MLP is learned by back propagation (BP), however, this algorithm often falls into local minimum. In proposed MLP, the glias' effects give energies to the MLP for escaping out from the local minima. We show an example of an output of the glial pulse propagating to two directions in Fig. 1. We can see that the 5th glia is excited by the connecting neuron and excites glias on both sides. After that, the glias pulses are generated into a chain reaction. Moreover, the exciting glias pattern can be dynamically changed during learning time. Because, the glias watch the neurons' outputs which are changed by the BP learning.

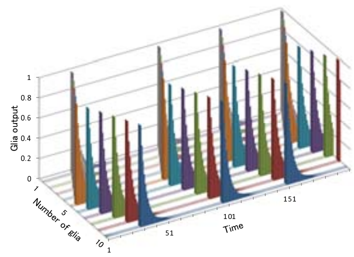

Figure 1: Example of glias' pulses as proposed method.

3. Simulation

In this simulation, the MLPs learn classification of two skew tent maps which are given by Eq. (3). We choose different A (0.1 and -0.1) of the skew tent maps, thus, the chaotic oscillation pattern changes. The MLP classifies the two different time series.

$$\phi_i(t+1) = \begin{cases} \frac{2\phi(t)+1-A}{1+A} & (-1 \le \phi(t) \le A) \\ \frac{-2\phi(t)+1+A}{1-A} & (A < \phi(t) \le 1) \end{cases}, \quad (3)$$

Table 1 is a statistic results of the MLPs which are an average of error (Avg. Err.), a minimum error as trials (Min.), a maximum as trials (Max.), and a standard deviation of error (St. Dev.). The number of trials are 100. We compare the four MLPs which are the conventional MLP (1), the MLP introducing glial pulse propagating to two directions (2), the MLP with pulse glial chain, and the MLP adding random noise (4). From this table, we can see that the proposed MLP has better learning performance than the others.

Table 1: Learning performance.

	Avg. Err.	Min.	Max.	St. Dev.
(1)	0.0085	0.0001	0.0612	0.0201
(2)	0.0012	0.0001	0.0602	0.0060
(3)	0.0048	0.0001	0.0641	0.0145
(4)	0.0067	0.0005	0.0620	0.0132

4. Conclusions

In this article, we have proposed the MLP introducing glial pulse propagating to two directions. The proposed method is inspired from features of the biological glia. The glias generate pulse by neurons' outputs and the pulse is affecting other glias and neurons. We showed that the proposed MLP has the better performance than the conventional MLPs by the simulation. We confirmed that the proposed method improved the MLP learning performance.

References

[1] P.G. Haydon, "Glia: Listening and Talking to the Synapse," *Nature Reviews Neuroscience*, vol. 2, pp. 844-847, 2001.