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Network with Chemical Messenger in Feed Forward Neural Networks

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1. Introduction

Neural Network (NN) and Deep Learning are made to imitate the human nervous system [1]. There are the following three substances constituting the human neural circuit. First, there are many nerve cells (neuron) in the human brain. Second, synapse connects to neurons and becomes junction for communicating information. Third, neurotransmitter is substances generated from synapse. It has a role to promote learning. Now, neuron and synapse are used in NN and Deep Learning. However, neurotransmitter is not used in NN and Deep Learning.

In this study, we propose new system of feed forward Neural Network (FFNN) having artificial neurotransmitter. We use characteristic of acetylcholine among neurotransmitter. We use this system and improve learning accuracy more than the conventional system.

2. Neurotransmitter

Neurotransmitter, also known as chemical messenger, is endogenous chemicals that enable neurotransmission. It is a neurotransmitter that is released from the synapse and cause an excitement or an inhibition reaction of neurons. More than 100 types are currently being confirmed.

In this study, we focus on acetylcholine what is one of the neurotransmitter. Acetylcholine was discovered by Henry Halletdale in 1914 and revealed to be a neurotransmitter by Otto Levy. It is early detection among neurotransmitters. It has many features. For example, it is secretion amount changes within 1 day. Secretion tends to decrease throughout the day. As a result, the learning function declines and you feel sleepy. However, you can restore the secretion of acetylcholine by having a meal. However, specific amount of secretion is unknown. It has a relationship with illness. It is known that too much acetylcholine secretion leads to Parkinson's disease. It is also known that too little acetylcholine secretion leads to Alzheimer's disease.

3. Proposed Method

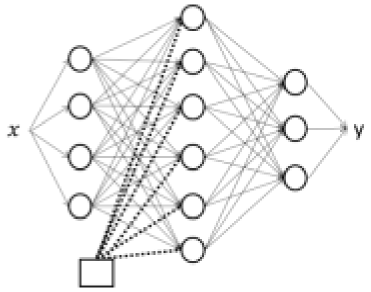
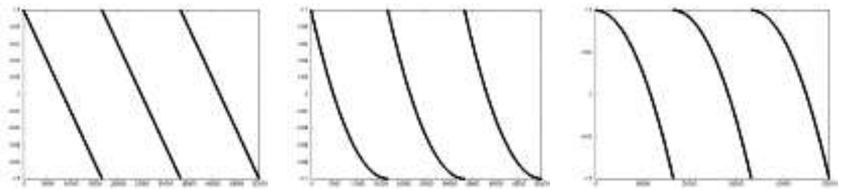


Figure 1 : A Schematic diagram of new system about FFNN using Iris data set.



(a) Pattern 1. (b) Pattern 2 . (c) Pattern 3.

Figure 2 : Three patterns which artificial characteristics of acetylcholine.

We use artificial characteristics of acetylcholine for the middle layer of FFNN. Proposed system that is used in this study is shown in Fig. 1.

Characteristics of acetylcholine are not fully understood yet. We use two reported characteristics of acetylcholine in this study. First, the amount of acetylcholine secretion varies in a daily life. Second, the amount of secretion recovers by having breakfast, lunch and dinner. For using these characteristics, we made two patterns which artificial characteristics of acetylcholine (Fig. 2). We consider the number of trials to be one day. So we decide to recover the secretion amount three times within learning loops. Pattern 1 shows that the amount of secretion decreases linearly at each learning loop. Pattern 2 shows that the amount of secretion amount of secretion decreases curvilinearly at each learning loop. Pattern 3 also shows that the amount of secretion decreases curvilinearly at each learning loop. And it shows that it decreases exponentially.

$$h_{ij}(t+1) = f\{\sum w_{ij}(t)(x(t)+\chi) - \theta(t)\} \quad (1)$$

Equation (1) describes the propagation equation of neuron having the acetylcholine's system at hidden layer.

4. Simulation Result

We compare with the minimum value of the average of learning error rate of 10 consecutive times. Learning error rate is determined by using root mean squared error. Root mean square error is expressed as Eq. (2).

$$\mathrm{A(y)} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_{learn} - y)^2} \quad (2)$$

y_{learn} is derived based on learning. y is the answer we have prepared. The weight correction constant is set to 0.1 in all systems.

We verify the proposed method using two data sets [2]. First, Iris data set has 150 data and used the network of the number of neurons in the input layer is 4, the number of neurons in the middle layer is 10 and the number of neurons in the output layer is 3. Second, $\mathrm{y} = x^2$ data set has 201 data. It learns the point of [-1, 1] of the function of $\mathrm{y} = x^2$. The network of the number of neurons in the input layer is 1, the number of neurons in the middle layer is 10 and the number of neurons in the output layer is 1. In Tables 1 and 2, "Conventional" shows the conventional system that does not have acetylcholine's system. Patterns 1, 2 and 3 show proposed systems that have features of acetylcholine. These features are shown in Fig. 2.

Table 1 : Learning error rate of using Iris data set.

System	Learning error rate
Conventional	0.05011
Pattern 1	0.04246
Pattern 2	0.04496
Pattern 3	0.04659

In Table 1, all proposed patterns obtain higher learning accuracy than the conventional system. In pattern 1, learning accuracy is improved by about 18%.

Table 2 : Learning error rate of using $\mathrm{y} = x^2$ data set.

System	Learning error rate
Conventional	0.00559
Pattern 1	0.00562
Pattern 2	0.00531
Pattern 3	0.00520

In Table 2, patterns 2 and 3 were able to reduce learning error rate compared with the conventional system. In pattern 3, learning error rate is reduced by about 7%.

4. Conclusion

First, new methods were proposed for FFNN using the property of acetylcholine, which is a neurotransmitter. Then, we used the amount of acetylcholine secretion decreases in a daily life and the amount of secretion recovers by having meals (breakfast, lunch and dinner). For using these characteristics, we made three patterns. As the results of verification in Iris data set, it was possible to reduce the error rate as compared with the conventional system.

We believe that the versatility of the neural network can be improved by using two methods for one system. We would like to challenge more realistic problems in the future.

Acknowledgment

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References

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