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Back Propagation Learning of an Affordable Neural Network for Chaotic Time Series

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1. Introduction

In Japan, cramming of too much knowledge into students was criticized and more relaxed education policy has been introduced to develop the individuality of each student. If students can afford to study carefully, creativity of the individual is fostered. We consider that it is very important to pay attention to "Affordable" concept in the field of engineering. In our previous research, we have proposed a new network structure with chaotically-selected affordable neurons in the hidden layer of the feedforward neural network for more efficient BP learning [1]. By computer simulations, the proposed neural network has been confirmed to gain better performance for the BP learning on both convergence speed and learning efficiency, when we set the feedforward neural network producing outputs x^2 for inputs data x as a learning example. However, only the results on one learning example can not conclude that the affordable neural network has an excellent ability for convergence speed and learning efficiency.

In this study, we investigate the performance of this neural network with chaotically-selected affordable neurons for unknown data which is chaotic time series generated by a skew tent map. Further, in order to confirm the effectiveness of the chaotic selection of the affordable neurons, we investigate performance of the network with affordable neurons selected regularly and at random. Computer simulated results show that the affordable neural network exhibits a good performance for the unknown input data.

2. Affordable Neural Network

We propose the network structure with chaotically-selected affordable neurons in the hidden layer of the feedforward neural network for more efficient BP learning. We introduce affordable neurons to reflect a function of the brain. The extra neurons in the hidden layer are prepared in advance. During the BP learning, all of the neurons in the hidden layer are not used at every updating. Namely, some of the neurons are selected for the learning and the rest of the neurons are deactivated. The network model with the affordable neurons is shown in Fig. 1.

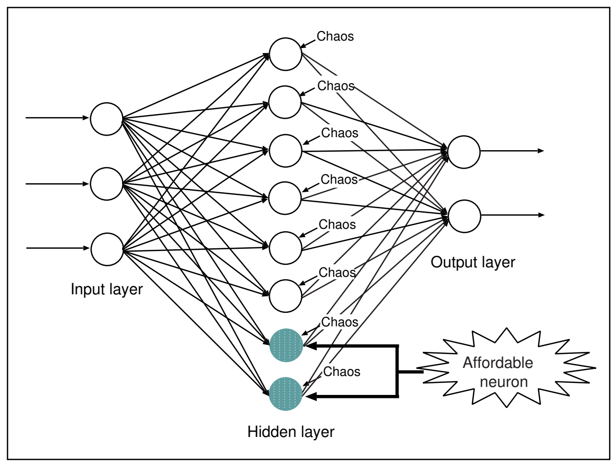


Figure 1: Network model with affordable neurons.

2.1. Chaotic Selection

For the proposed network, some of the neurons have to be selected at every updating of the BP learning. The authors have investigated the performance of the Hopfield neural network solving combinatorial optimization problems when chaos is inputted to the neurons as noise [2]-[4]. By computer simulations, chaotic noise has been confirmed to gain better performance to escape out of local minima than random noise. Hence, we consider that various features of chaos are effective for neural networks.

In this study, we use the skew tent map as a simple chaotic map to realize chaotic selection of operating neurons in the hidden layer. We prepare the skew tent maps with different initial values, whose number is the same as the number of the neurons in the hidden layer, and each skew tent map is corresponded to each neuron. At the every updating of the

BP learning, the skew tent maps are also updated and their values are referred. We select a certain number of the neurons in the order of the values of the skew tent maps. Hence, the selection is made in a chaotic manner. Note that chaos is not inputted to the neural network directly, but is used only for the selection of the operating neurons. The skew tent map is defined by the following equation and the map is shown in Fig. 2.

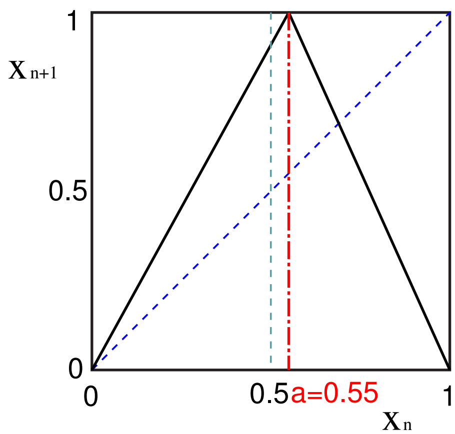


Figure 2: Skew tent map.

$$x_{n+1} = \begin{cases} \dfrac{x_n}{0.5+a} & (0 \leq x_n \leq a) \\ \dfrac{-x_n+1}{1-a} & (a < x_n \leq 1) \end{cases} \quad (1)$$

2.2. Regular and Random Selection

In order to confirm the effectiveness of the chaotic selection of the affordable neurons, we also investigate the performance of the BP learning of the network with affordable neurons selected other non-chaotic methods, namely regular method and random method. For the regular method, the operating neurons in the hidden layer are selected in order. For the random method, the operating neurons in the hidden layer are selected completely at random.

3. Simulated Results

The standard BP learning algorithm was introduced in [5]. The BP is the most common learning algorithm for feedforward neural networks. In this study, we use the batch BP learning algorithm. The batch BP learning algorithm is expressed by similar formula of the standard BP learning algorithm. The difference lies in the timing of the update of the weight. The update of the standard BP is performed after each single input data, while the update of the batch BP is performed after all different input data.

In this study, after learning of the affordable neural network, we input an unknown chaotic time series generated by skew tent map as another learning data. We investigate the affordable neural network producing the same output as the input data. Further, we compare three cases "chaos", "regular" and "random" method as selection of the affordable neurons. We prepare 20 neurons in hidden layer and the number of affordable neurons is changed as 0 to 10. If the number of affordable neurons is 0, the network has a normal (conventional) hidden layer structure. However, if the number of affordable neurons is 10, only 10 neurons of 20 neurons in hidden layer are operated at every update time.

Next, we explain about the learning of the network. We consider the feedforward neural network producing the same chaotic time series as the inputed chaotic time series generated by a skew tent map as one learning example. The length of chaotic time series is set to 10 and the number of learning data is set to 100. We carried out the BP learning by using following parameters. The parameter of the inertia rate is fixed as $\eta = 0.05$ and initial values of the weights are given between -1.0 and 1.0 at random. The learning time is set to 20000.

3.1. Conventional network

In order to make clear the reason why affordable neural network gains good performance for unknown input data, we investigate the performance of the conventional neural network without affordable neurons. The simulation result of conventional network is shown in Fig. 3. The horizontal axis is time and vertical axis is unknown chaotic time series generated by the skew tent map. From this figure, we can see that the performance of conventional neural network does not work well for unknown input data. Because, the error of output for input data is 0.1023.

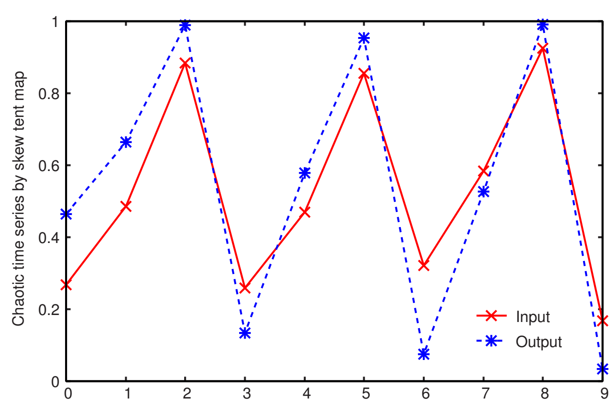
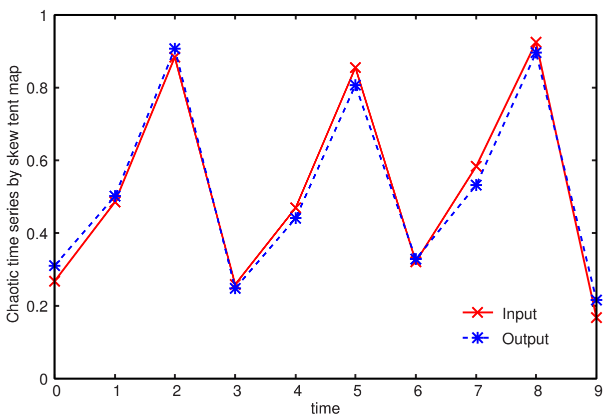


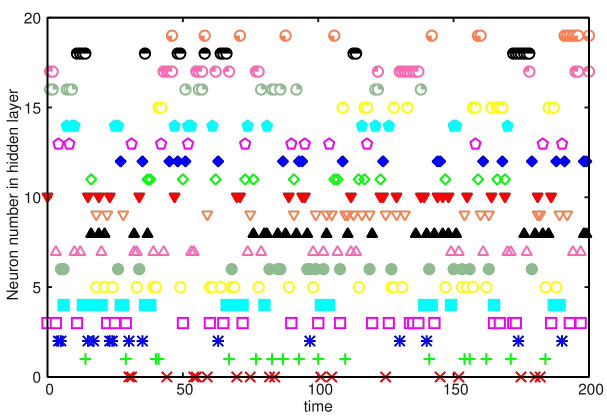
Figure 3: Input and output data of conventional network (error: 0.1023).

3.2. Affordable neural network using CHAOS selection

Figure 4(a) shows the output data for unknown input data using by chaos selected affordable neural network. The horizontal axis is time and vertical axis is unknown chaotic time series generated by the skew tent map. From this figure, we consider that the chaos selected affordable neural network can output the same unknown input data and the error is 0.0059. Next, the state of selected affordable neurons is shown in Fig. 4(b). The horizontal axis is time and vertical axis is neuron number in hidden layer. The plotted marks mean to selected as affordable neuron at each updating. We can see that the affordable neurons are selected chaotically.



(a) Input and output data (error: 0.0059).

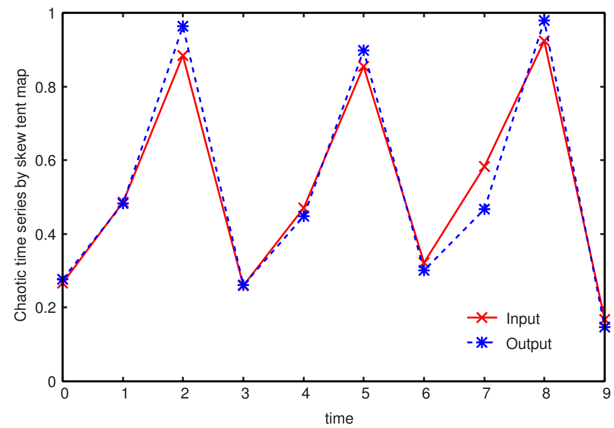


(b) Selected affordable neurons.

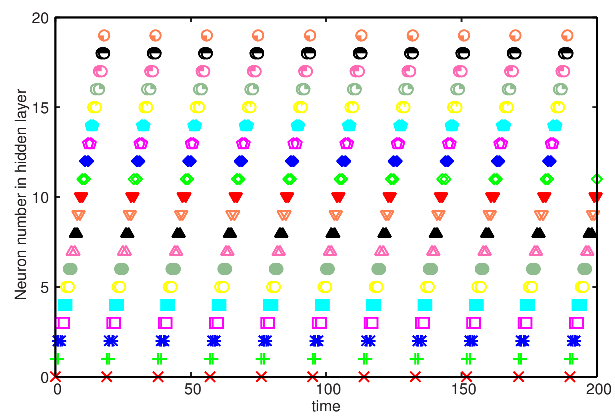
Figure 4: Chaos selection (the number of affordable neurons: 2).

3.3. Affordable neural network using REGULAR selection

Figure 5(a) shows the output data for unknown input data using by regular selected affordable neural network. From this figure, we consider that the regular selected affordable neural network gains better performance than the conventional network. However, this regular selection method does not to be compared with chaos selection method. Because the error of the network for output is 0.0129. Next, the state of selected affordable neurons is shown in Fig. 5(b). We can see that the affordable neurons are selected regularly.



(a) Input and output data (error: 0.0129).

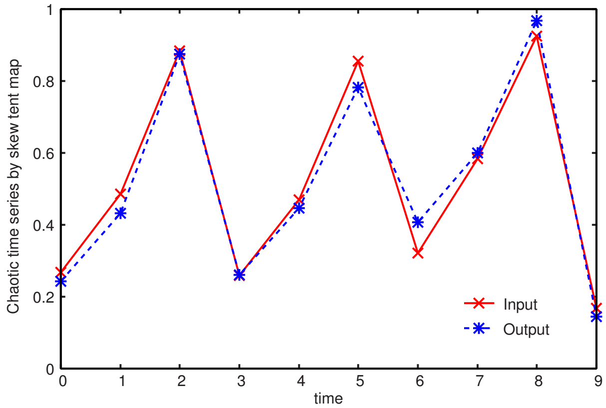


(b) Selected affordable neurons.

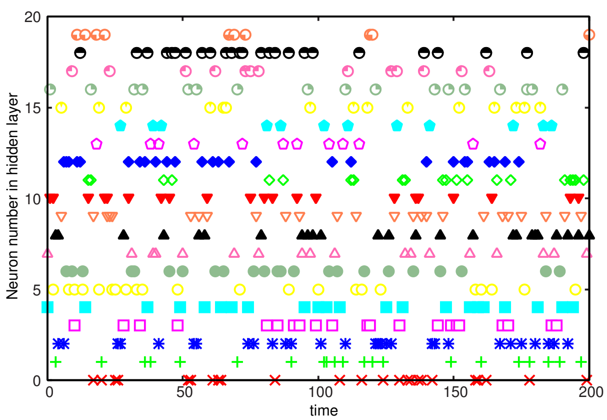
Figure 5: Regular selection (the number of affordable neurons: 2).

3.4. Affordable neural network using RANDOM selection

Figure 6(a) shows the output data for unknown input data using by random selected affordable neural network. From this figure, we consider that the regular selected affordable neural network almost can output the same unknown input data and the error is 0.0098. Next, the state of selected affordable neurons is shown in Fig. 6(b). We can see that the affordable neurons are selected at random.



(a) Input and output data (error: 0.0098).



(b) Selected affordable neurons.

Figure 6: Random selection (the number of affordable neurons: 2).

3.5. Comparison of three selection methods

Finally, we investigate the performance of three selection methods, when the network structure of the hidden layer is changed. The simulation result is shown in Fig. 7. The horizontal axis is the number of affordable neurons and the vertical axis is the error for the unknown input data. In this figure, we confirm that the neural network with some affordable neurons gains the better performance than the network without affordable neurons in hidden layer. However, when the number of the affordable neurons exceeds 4, the performance of the network gradually becomes worse because the number of operating neurons decrease and the networks become sluggish. Further, we confirm that the chaos selection and the random selection gain better performances than the regular selection.

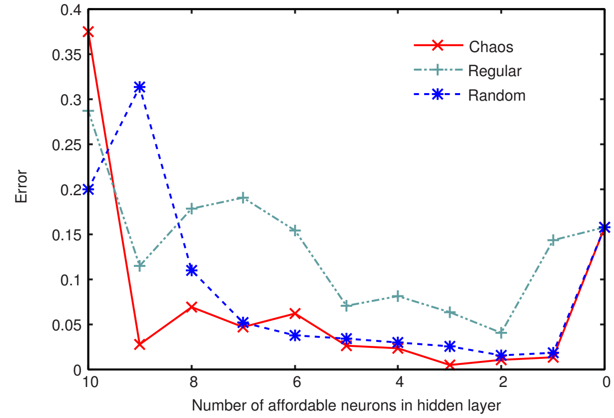


Figure 7: Error for unknown data.

4. Conclusions

In this study, we applied this neural network with chaotically-selected affordable neurons to learning unknown chaotic time series generated by skew tent map. Computer simulated results showed that the affordable neural network exhibits a good performance for the unknown input data. Further, we confirmed that the chaotic and random selection of affordable neurons was important to obtain the good performance. These results of the affordable neural network are used the noise reduction in chaos communication [6].

References

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