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Effect of Real Biological Chaos on Solving Ability of Neural Network

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1. Introduction

In the optimization problems, many algorithms pouring chaotic oscillations to the Neural Networks (NN) have been proposed in order to avoid the local minimum problems [1]. We have also investigated various methods to exploit chaotic features to enhance the ability of the neural networks. However, in the past studies, only mathematical abstract models, e.g. the logistic map and the cubic map, are considered as chaotic source.

In this study, in order to investigate the effect of chaotic oscillations of real biological signals, we use chaotic pulse waves obtained by real biological experiments and pour the sampled chaotic data to the Hopfield NN solving Traveling Salesman Problems (TSP). By computer simulations, we investigate the effect of the chaotic pulse wave. We also compare the results with the case of random noise.

2. Hopfield NN solving TSP

In this study, we choose 2 problems "bayg29" and "att48" from TSPLIB [2].

For solving N-element TSP by Hopfield NN, $N \times N$ neurons are required. The state of $N \times N$ neurons are asynchronously updated due to the following difference equation:

$$x_i(t+1) = f\left(\sum_{j,n=1}^{N} \omega_{im;jn}\, x_{jm}(t) - \theta_{im}(t) + \beta z_{im}(t)\right) \qquad (1)$$

where f is sigmoidal function. z_{im} is additional noise, namely chaotic pulse wave in this study.

3. Chaotic pulse wave

We obtained pulse waves from real biological experiments. The sampling frequency of the data is 200Hz and measurement time is 5 minutes. The time waveform of the pulse wave and the corresponding reconstructed attractor are shown in Figs. 1 (a) and (b), respectively. We calculated the averaged Lyapunov exponent as 4.5032 and hence we can say this pulse wave is chaotic.

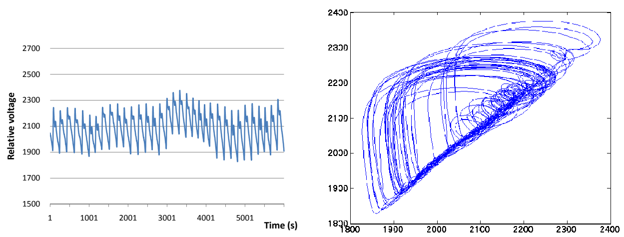

Figure 1: Chaotic pulse wave. (a) Example of pulse waves. (b) Example of recomstructed attractors of pulse wave.

In order to pour this chaotic pulse wave to the Hopfield NN, we normalize the wave and use only one of every 30 samples. Further, in this study, we fix the amplitude parameter β=0.7.

4. Simulation results

We carry out computer simulations for 10 times of 100 iterations and recorded the minimum and the average values of the tour length. The simulated results of 4 subjects (A, B, C, D) are summarized in Figs. 2(a) and (b). We compared the results with the result of random noise case.

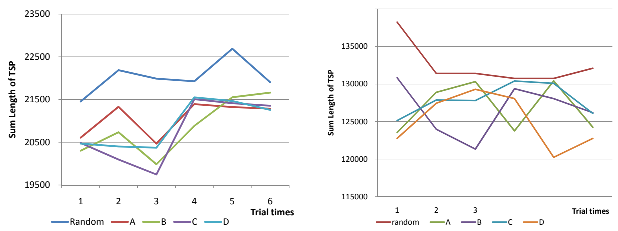

Figure 2: Simulated results. (a) Simulated results of bay29. (b) Simulated results of att48.

The results are summarized in Table 1. From this table, we can confirm that the chaotic pulse wave gains better performance than the random noise.

Table 1: Simulated results.

	bay29	Err.	att48	Err.
Noise	22025	143%	132448	295%
A	21068	132%	126859	278%
B	20853	130%	126624	278%
C	20767	129%	127897	282%
D	20920	131%	125090	273%

5. Conclusions

We have investigated the effect of the chaotic pulse wave poured in the Hopfield NN solving TSP. By carrying out computer simulations for the problem, we have confirmed that the chaotic pulse wave had an effect to avoid local minimum problems and achieved a performance to find good solutions of TSP.

In this study, we could not obtain an enough results to conclude on the relationship between the performance of the neural networks and the stress added to the subject. That is our important future research topic.

References

[1] Y. Hayakawa and Y. Sawada, "Effects of chaotic noise on the performance of a neural network model for optimization problems," Physical Review E, vol.51, no.4, pp.2693–2696, 1995.

[2] "TSPLIB," http://www.iwr.uni-heidelberg.de/groups/comopt/software/TSPLIB95/