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Hopfield NN with Chaotic Pulse Wave Solving Traveling Salesman Problems

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1. Introduction

The Traveling Salesman Problems (TSP) is one of the applications of the Hopfield Neural Networks (Hopfield NN). However, the Hopfield NN often stops at local minimum and does not give a good solution. Many algorithms pouring chaotic oscillations to the networks have been proposed in order to avoid the local minimum problems [1].

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. We compare the performances of the Hopfield NN solving TSP with random noise and chaotic pulse waves.

2. Hopfield NN solving TSP

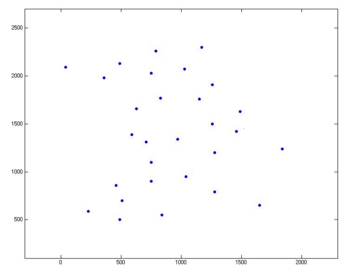

Figure 1: An example of TSP.

In this study, we choose a problem "bayg29" from TSPLIB [2]. The map points of "bayg29" is shown in Fig. 1.

For solving N-element TSP by Hopfield NN, $N \times N$ neurons are required and the following energy function is defined to fire (i, j)th neuron at the optimal position:

$$E = \sum_{i,m=1}^{N} \sum_{j,n=1}^{N} \omega_{im;jn} x_{im} x_{jn} + w_{ij} \sum_{i,m=1}^{N} \theta_{im} x_{im} \qquad (1)$$

The state of $N \times N$ neurons are unsynchronously updated due to the following difference equation:

$$x_i(t+1) = f\left(\sum_{j,n=1}^{N} \omega_{im;jn} x_{jm}(t) - \theta_{im}(t) + \beta z_{im} \right) \qquad (2)$$

$$f(a) = \frac{1}{1+e^{-a}} \qquad (3)$$

where z is random noise or chaotic pulse wave, the function f is the sigmoidal output function, and β controls the amplitude of the additional random noise or chaotic pulse wave.

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 Fig. 2 and Fig. 3, respectively. We calculated the averaged Lyapunov exponent as 4.5032 and hence we can say this pulse wave is chaotic.

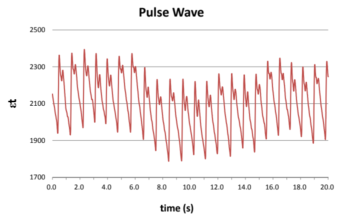

Figure 2: Pulse Wave.

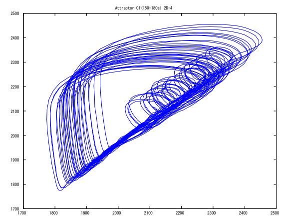

Figure 3: Attractor of Pulse Wave.

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 1000 iterations and recorded the minimum and the average values. The simulated 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.

	pulse wave	random noise
minimum	2.0398e+04	2.2464e+04
average	2.6428e+04	2.6652e+04

5. Conclusions

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

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/