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Effect of Chaos Noise to Matrix Elements with Hopfield Neural Network for QAP

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1 Introduction

Although it would be possible to solve combinatorial optimization problems with a huge number of elements if we have infinite long time, it does not make any sense for practical problems. The Hopfield Neural Network (NN) is used by many researchers for solving combinatorial optimization problems [1]. However, the solutions are trapped into the local minima. To obtain an optimal soltion, the solution needs to avoid the local minima.

In this study, we propose an algorithm that pouring chaos noise to matrix elements of quadratic assignment problem (QAP) with Hopfield NN. It supports to avoid local minima and to find good solutions. By carrying out computer simulations, we confirm that the chaos noise has a good effect to avoid local minima and achieves a good performance to find a good solution of QAP.

2 Solve to QAP with Hopfield NN

The QAP of N-element is expressed by two $N \times N$ matrixes, the distance matrix D and the flow matrix F. The objective function $C(p)$ is given as follows;

$$C(p) = \sum_{i=1}^{N} \sum_{j=1}^{N} D_{ij} F_{p(i)p(j)}, \quad (1)$$

where D_{ij} and F_{ij} is the (i,j)-th elements of D and F, $p(i)$ is the (i)-th element of vector p, N is the size of problem, respectively. A good solution becomes close to the minimum value of $C(p)$.

For solving N-element QAP by Hopfield NN, $N \times N$ neurons are required. The states of $N \times N$ neurons are asynchronously updated as following Eq. (2).

$$x_{im}(t+1) = f\Big(\sum_{j,n=1}^{N} w_{im;jn} x_{im}(t) x_{jn}(t) - \theta_{im} + \beta z_{im}(t)\Big), \quad (2)$$

where z_{im} is additionnal chaos noise, β limits the amplitude of noise. In this study, we use the noise poured to matrix elements of QAP.

3 Chaos noise

In this study, we use the time series of the chaos generated by the logistic map as a noise. The logistic map is given as following equation.

$$x_n(t+1) = \alpha x_n(t)(1 - x_n(t)), \quad (3)$$

The chaotic sequence is normalized by

$$\hat{x}_n(t) = \frac{x_n(t) - \bar{x}}{\sigma_x}, \quad (4)$$

where $\bar{x}$ is the average of x_n and σ_x is the standard devision of x_n. In this study, we use the bifurcation parameter $\alpha = 3.828$. The bifurcation parameter $\alpha = 3.828$ is the intermittency chaos near the three-periodic window obtained from the logistic map. It is reported that the intermittency chaos near the three-periodic window obtained from the logistic map gains good performance for combinatorial optimization problems [2]. The chaotic sequence is shown in Fig. 1.

The initial conditions are difference when the noise is poured to the Hopfield NN or matrix elements.

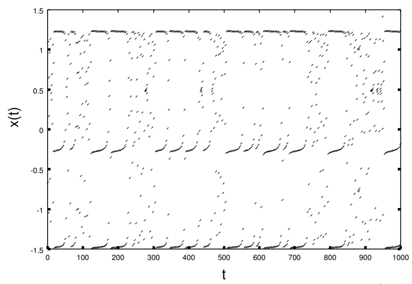

Figure 1: The time series of logistic map ($\alpha = 3.828$).

4 Simulated results

In this study, we use the problem, “Nug12” from QAPLIB. The optimal solution of this problem is known “578”. The results are summarized in Table 1. Here, the number of iterations is from 1000 to 5000 times. The results are average values of 10 trials. The prameter of Hopfield NN is $A = 0.9$, $B = 0.9$, $q = 140$ and $\epsilon = 0.02$.

In Table 1, the conventional method is Hopfield NN with chaos noise only for state (2). The proposed method 1 is Hopfield NN with chaos noise poured to two matrixes. The proposed method 2 is Hopfield NN with chaos noise poured to distance matrix.

Table 1: Solving to “Nug12 ”.

Iteration	Conventional method	Proposed method 1	Proposed method 2
1000	643.8	638.4	623.6
2000	640.6	628.6	623.2
3000	635.6	628.0	620.2
4000	633.8	625.6	620.2
5000	631.6	624.6	617.4

From this table, we can confirm that the proposed algorithm exhibits better performance than the conventional method and the distance matrix with chaos noise is the best performance at every iterations.

5 Conclusions

We have investigated the effect of chaos noise poured to the matrix elements with Hopfield NN for the QAP. By carrying out computer simulations, we have confirmed that the chaos noise had a good effect to avoid local minimum problems and achieved a good performance to find good solutions of the QAP.

As the future subject, we will investigate the effect to pour different noises to the elements.

References

[1] Y. Uwate and Y. Nishio, “Search of Many Good Solutions of QAP by Connected Hopfield NNs with Chaos Noise,” *Proc.of NCSP'04*, pp. 145-148, Mar. 2004.

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