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# Hopfield NN for QAP with Noise of Different Amplitudes

Yoshifumi Tada Yoko Uwate Yoshifumi Nishio
(Tokushima University)

## 1. Introduction

Solving combinatorial optimization problems are one of the important applications of the neural network (NN). In this study, we investigate solving ability of Hopfield NN for Quadratic Assignment Problem (QAP) when the amplitude of injected noise is changed.

## 2. Solving QAP with the Hopfield NN

For solving $N$-elements QAP by the Hopfield NN, $N\times N$ neurons are required. $N\times N$ neurons Hopfield NN model is shown in Fig.1. The following energy function is defined to fire $(i,j)$-th neuron at the optimal position:

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

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

$$x_{im}(t+1)=g\left(\sum_{i,n=1}^{N}\omega_{im;jn}x_{jn}(t)+\theta_{im}+\beta z_{im}(t)\right) \quad (2)$$

where $z_{im}$ is additional noise, $g$ is sigmoidal function, and $\beta$ limits amplitude of the noise.

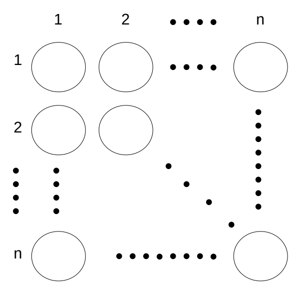


Figure 1: $N\times N$ neurons Hopfield NN model.

## 3. Chaos Noise

The Logistic map is used to generate chaos noise.

$$\hat{z}_{im}(t+1)=\alpha\hat{z}_{im}(t)(1-\hat{z}_{im}(t)). \quad (3)$$

When we inject the chaos noise to the Hopfield NN, we normalize $\hat{z}_{im}$ by Eq. (4)

$$z_{im}(t)=\frac{\hat{z}_{im}(t)-\bar{z}}{\sigma_z} \quad (4)$$

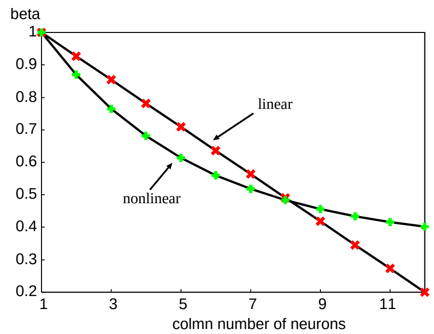


Figure 2: Amplitude $\beta$.

where $\bar{z}$ is the average of $\hat{z}(t)$, and $\sigma_z$ is the standard deviation of $\hat{z}(t)$.

In this study, we propose a method that the amplitude $\beta$ of the injected noise is changed by the column number of neurons. The amplitude $\beta$ is changed according to a linear and a nonlinear functions Fig. 2. The nonlinear function is obtained by an exponential function.

## 4. Simulated Results

The problem used here was chosen from the site QAPLIB named "Nug12." The global minimum of this target problem is known as 578. We fixed the amplitude parameter as $\beta = 0.6$ in the conventional method. We carried out 10 trials 10000 iterations for each methods.

Table 1 shows the simulation results. The results show that our method gains better performance than the conventional method. And the nonlinear function has better performance than the linear function.

Table 1: Simulation results.

| iteration | nonlinear | linear | conventional |
|---|---|---|---|
| 2000 | 605.8 | 608.8 | 616.6 |
| 4000 | 604.2 | 603.0 | 611.0 |
| 6000 | 594.4 | 599.0 | 610.8 |
| 8000 | 592.6 | 598.2 | 609.8 |
| 10000 | 591.2 | 598.2 | 608.8 |

## 5 Conclusions

In this study, we have investigated solving ability of Hopfield NN for QAP when the injecting amplitude noise is changed. We confirmed that the proposed method is effective to local minimum problems.