2009 IEEE Workshop on
Nonlinear Circuit Networks, Tokushima, Dec 11-12, 2009

Effect of Chaos Noise to City Placement with Or-opt Algorithm for TSPs

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***Abstract*— In this study, we propose an novel algorithm pouring the chaos noise to the city placement for solving the traveling salesman problems. We investigate the effect of chaos noise poured in the city placement with 2-opt algorithm and Or-opt algorithm. In addition, we investigate changing the amplitude of chaos noise poured in the city placement. By carrying out computer simulations for various problems, we confirm that the chaos noise has a good effect to avoid local minima and achieves to a good solution of the traveling salesman problems.**

I. 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. In several approximation methods, the solutions are trapped into local minima and do not escape. In order to avoid this problem, technical methods to escape from local minima are required.

Many researchers have proposed that the approximation method with the chaos noise [1][2]. The chaos noise is directly poured to the algorithm in these proposed method.

In this study, we propose an algorithm that pouring the chaos noise to the city placement. It supports to find good solutions and avoid local minima. In the past study, we have investigated the effect of chaos noise poured in the city placement with 2-opt algorithm [3], hence we extend the idea to more strong Or-opt algorithm and changing the amplitude of choas noise.

The traveling salesman problems(TSPs) is one of the combinational optimization problems, which is described as follows: given city placements, find the minimum length tour which visits each city exactly once [4]. The TSP belongs to a class of NP-hard in the computational complexity. Solving for TSPs, it is reported that the good solution is achieved to used by neural network as other efficient method [5][6].

In this study, we propose an novel algorithm pouring the chaos noise to the city placement for solving the traveling salesman problems. Furthermore, we compare changing the amplitude of noise and the several types of noises such as intermittency chaos, fully developed chaos and random noise. By carrying out computer simulations for various problems, we confirm that the chaos noise has a good effect to avoid local minima and achieves a good solution of the TSPs.

II. Proposed Method

In the approximation methods, the solutions are trapped into local minima. Therefore, it is important to develop effective methods to avoid the local minima. In this study, we propose an novel algorithm that the chaos noise is poured to the city placement.

The simulations are carried out according to the following procedure.

- Step1 The 2-opt algorithm exchanges two paths for other paths.
- Step2 The Or-opt algorithm exchanges multiple paths for other paths.
- Step3 Pouring the noise to city placement, the city placement is changed.
- Step4 Step. 1 - Step. 3 repeats several times.

These procedure details following below;

A. 2-opt algorithm

The 2-opt algorithm exchanges two paths for other two paths until no further improvement can be obtained. Figure 1 shows an example of the 2-opt exchange. In Fig. 1, the 2-opt algorithm exchanges two paths, i-j and k-l, with the another two paths, i-k and j-l, where j and l are cities next to i and k. If a trial exchange shortens total tour length, the exchange is really executed.

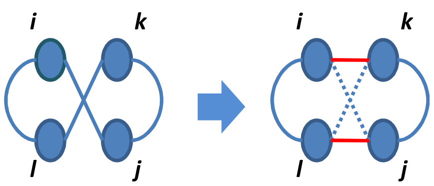

Fig. 1. Example of 2-opt exchange.

B. Or-opt algorithm

The Or-opt algorithm exchange multiple paths in a similar to 2-opt algorithm. In this study, the Or-opt exchanges after the 2-opt exchanged. The Or-opt exchange is the 3-opt exchange at a maximum containing the 2-opt algorithm. Therefore, the Or-opt algorithm can find new candidates which the 2-opt algorithm is not able to find.

C. Pouring Noise

To avoid local minima, we propose the noise poured to city placement. The noise is poured in the city placement after the Or-opt exchange. Namely the city placement is changed by the noise, the 2-opt algorithm and Or-opt algorithm find new candidates for exchange. The city placement returns the initial state after the new candidates are found by 2-opt exchange and Or-opt exchange. The 2-opt algorithm and Or-opt algorithm are searching the new path again.

To be iterated these processes, the solutions avoid the local minima and achieve the good solutions.

III. 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.

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

The chaotic sequence is normalized by following equation.

$$\hat{x}_n(t) = \frac{x_n(t) - \bar{x}}{\sigma_x} \quad (2)$$

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 $\alpha = 3.828$ and $\alpha = 4.0$. The bifurcation parameter $\alpha = 3.828$ is the intermittency chaos near the three-periodic window obtained from the logistic map. As we can see from the Fig. 3, the chaotic time series is divided into two phases; laminar parts of periodic behavior with period three and burst parts of spread points over the invariant interval. It is reported that the intermittency chaos near the three-periodic window obtained from the logistic map gains better performance for combinatorial optimization problems than the fully-developed chaos. The bifurcation parameter $\alpha = 4.0$ is the fully-developed chaos. As we can confirm from Fig. 4, the fully-developed chaos consists of burst parts and do not have laminar parts.

IV. Simulation Results

In this study, we apply the proposed algorithm for four problems, “kroE100”, “lin105”, “pr124” and “pr226” from TSPLIB [7]. The simulated results are summarized in Table 1. Here, the number of iterations is 100 times. The simulated results are average values of 10 trials with different initial value. Table 1 shows the results of the Or-opt algorithm without chaos (conventional method), the Or-opt algorithm with chaos noise of the bifurcation parameter $\alpha = 3.828$ (intermittency chaos), $\alpha = 4.0$ (fully-developed chaos) and random noise (random), respectively. We investigate two patterns of the amplitude in poured noise (amplitude = 0.01, decreasing from 0.01 to 0.0001).

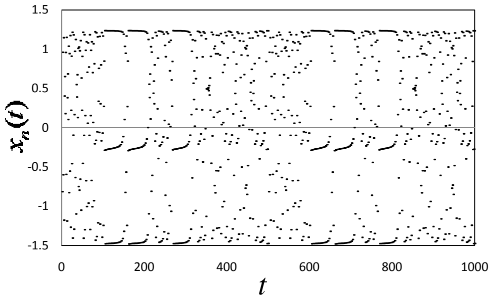

Fig. 2. Intermittency chaos ($\alpha = 3.828$).

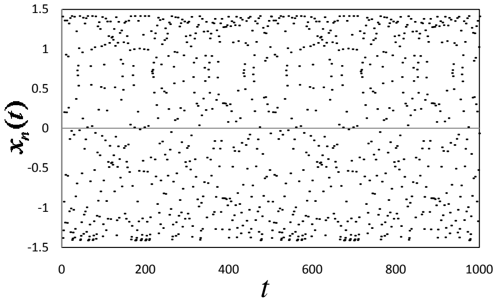

Fig. 3. Fully-developed chaos ($\alpha = 4.0$).

TABLE I

The results of conventional method, chaos noise, random noise

Problem	kroE100	lin105	pr124	pr226
Optimal solution	22068	14379	59030	80369
Conventional method	22550	14790	60512	84111
Random amplitude = 0.01	22606	14995	60231	84663
Intermittency chaos, amplitude = 0.01	22396	14804	60321	83019
Fully-developed chaos, amplitude = 0.01	22456	14903	60321	84086
Random decreasing amplitude	22146	14425	59092	81131
Intermittency chaos, decreasing amplitude	22153	14401	59087	81044
Fully-developed chaos, decreasing amplitude	22154	14405	59087	81186

From this table, we can confirm that the Or-opt algorithm with noise exhibits better performance than the conventional method without noise. Although the averaged values are similar for all four proposed methods, the method with the intermittency chaos seems to be more effective to find the best solution. In the method with the intermittency chaos, decreasing the amplitude from 0.01 to 0.0001, the solutions become close to the optimal solution.

V. Conclusion

We have investigated the effect of chaos noise poured in the city placement with 2-opt algorithm and Or-opt algorithm for the TSPs. By carrying out computer simulations for various problems, we have confirmed that the chaos noise had a good effect to avoid local minimum problems and achieved a good solutions of the TSPs.

As the future subject, we will investigate the effect to pour different noises to the city placement and use the other algorithm for searching tour length.

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