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Consideration of Diverse Solutions Genetic Algorithm with Virus Infection for Traveling Salesman Problem

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Abstract—Genetic Algorithm (GA) is known as one of method to solve Traveling Salesman Problem (TSP). However, GA needs amount of time for finding approximate solution. In our previous study, we have proposed Genetic Algorithm with Virus Infection (GAVI). GAVI algorithm is used Virus Theory of Evolution (VTE) to be based on GA. Characteristic of VTE is effective for finding approximate solution. Thus, GAVI obtains more effective result than GA. However, GAVI does not make consideration of diverse solutions. In this study, we propose new algorithm to make consideration of diverse solutions. This proposed algorithm is named Consideration of Diverse Solutions Genetic Algorithm with Virus Infection (DS-GAVI). We apply DS-GAVI to TSP and confirm that DS-GAVI obtains effective solutions for leading approximate solution.

1. Introduction

Traveling Salesman Problem (TSP) [1] is known as one of the combinatorial optimization problems. When Salesman tours all cities at once, TSP is the problem of finding minimum total between each city distance in route. Then n is the number of cities in TSP, total route number increase at rate proportional to many of the factorial of n. Therefore, exploring total route number needs amount of time for finding approximate solution. It is necessary to solve the TSP in other ways except exploring total routes.

Genetic Algorithm (GA) [2], [3] is one of the popular method in variety of ways to solve the TSP and is studied by many researchers all over the world. GA is modeling behavior of evolution in organic, and is to explore the solution for repeating crossover on the basis of organic evolution. Thus, GA needs overlaying the generation for obtaining approximate solution. Whereat, in our previous study, we have proposed Genetic Algorithm with Virus Infection (GAVI) [4]. GAVI is used Virus Infection algorithm based on GA. One of the characteristics of the Virus Infection [5]-[7] is infection other same generations at once. This characteristic seemed to be useful for finding the approximate solution quickly. Therefore, we confirmed that VTE is efficient in TSP.

However, GAVI does not make consideration of diverse solutions. Moreover, in using the Virus Infection algorithm, gene group are easy to have similar nature. Because characteristics of the Virus Infection is to convey part of gene information to other genes. In this study, we propose new algorithm to make consideration of diverse solutions. This proposed algorithm is named Consideration of Diverse Solutions Genetic Algorithm with Virus Infection (DS-GAVI). If algorithm does not make consideration of diverse solutions, gene group would tend to have similar nature. Thus, algorithm is difficult to escape local minimum, and needs consideration diverse solutions for obtaining better solution. We carry out computer simulations for various parameter values and confirm that DS-GAVI achieves better performance than GAVI.

2. Virus Theory of Evolution

Organic evolution is theory based on natural selection. In the natural world, high fitness individuals organism survive, while low fitness individuals organism become extinct. Over the years, only higher fitness individuals survive. We call it evolution. Thus, evolution need to overlay generations.

On the other hand, there is theory named by Virus Theory of Evolution (VTE) [8]. This theory is based on the evolution by Lateral Gene Transfer (LGT) [9] in Virus infection. LGT is uptake of the gene that occur between other individuals and among other species. Without evolution inherited from parent cell to child cell, genes can evolve. Low fitness individuals possibly evolve into high fitness individuals in just one generation by LGT in Virus infection. In other words, we assume that each individual become a better evaluation value quickly. Thus, we assume using VTE algorithm leads the approximate solution in less time and VTE theory is efficient in TSP.

3. Diverse Solutions Genetic Algorithm with Virus Infection (DS-GAVI)

GAVI is a method of VTE algorithm in Virus infection to be based on GA. DS-GAVI is used both Good Selection and Bad Selection in combination to keep diverse solutions. Good Selection tends to be chosen high evaluation route. While, Bad Selection tends to be chosen low evaluation route. Figure 1 shows the flow chart of DS-GAVI. t_{max} is number of repeating times. DS-GAVI algorithm is indicated the following Step1-7. Step2-7 is repeated until the set number of crossover times. After the set number of crossover times, DS-GAVI output the best solution in all getting solutions.

step1 (Initialization)

Initialization is random route selection. Number of random route selection is U.

step2 (Evaluation)

Evaluation is defined by the following formula.

$$f_i = \frac{1}{d_i} \tag{1}$$

where d_i is total distance of each route and f_i is evaluation value. If d_i is low, f_i is high by this formula.

step3 (Selection)

In this study, we apply two selection method. The first method tends to be chosen high evaluation route. We call this method Good Selection. In Good Selection, route is selected with a probability of pg_i. pg_i is defined by the following formula. Where n is the number of cities.

$$pg_i = \frac{f_i}{\sum_{i=1}^{n} f_i} \tag{2}$$

While, the second method tends to be chosen low evaluation route. We call this method Bad Selection. In Bad Selection, route is selected with a probability of pb_i.

$$pb_i = \frac{d_i}{\sum_{i=1}^{n} d_i} \tag{3}$$

We use the both Good Selection and Bad Selection in combination.

step4 (Fulfill crossover condition)

This section evaluates crossover condition. If parents is not fulfill crossover condition, crossover is not action. when crossover condition is fulfill, crossover is action.

step5 (Crossover)

Crossover is to be mated the two routes. In this study, we apply sub tour exchange crossover. This way makes a search for sub tour of Both Parent A and Parent B in common. If it does not find sub tour in common, crossover is not action. For example, between $1, 2, 5, 6$ and $5, 1, 6, 2$ are sub tour in Fig. 2. $1, 2, 5, 6$ and $5, 1, 6, 2$ are differ in line, however these are same class. Sub tour in $1, 2, 5, 6$ can express $1, 2, 5, 6$ and $6, 5, 2, 1$, $5, 1, 6, 2$ can express $5, 1, 6, 2$ and $2, 6, 1, 5$. Because two expressing are same about total route distance in Fig. 3. Thus, after crossover, four child exist.

step6 (Infection)

Infection is incorporating partial optimum solution. The best individual, which gives the shortest tour in each generation, is defined as a Virus. The infection to other individuals is decided with a fixed probability. The infection is made as copying some elements of the Virus, where the position and the size are selected at random. For example, $3, 5$ is a virus and has infected the route of $6, 1, 3, 5, 2, 4$ in Fig. 4. Infection part determines $1, 4$ in the route. The route replace to $3, 5$ $1, 4$. We call it Infection.

step7 (One route reset in random)

If a obtained solution is same among number of s, one route in all routes is initialization at random. $O(t)$ is the obtained solution in number of t times, while $O(t-s)$ is obtain solution previous number of s. Thus, $O(t) = O(t-s)$ shows that the obtained solution is same among number of s. We assume that this is efficient to escape local minimum.

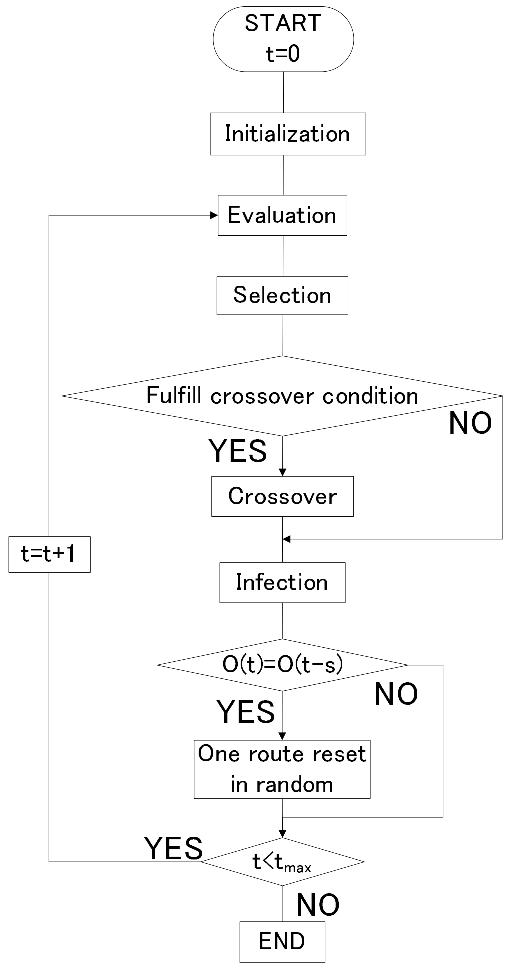

Figure 1: Flow chart of DS-GAVI.

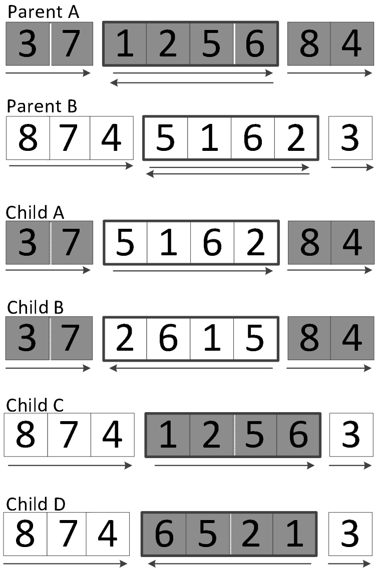

Figure 2: The mechanism of crossover.

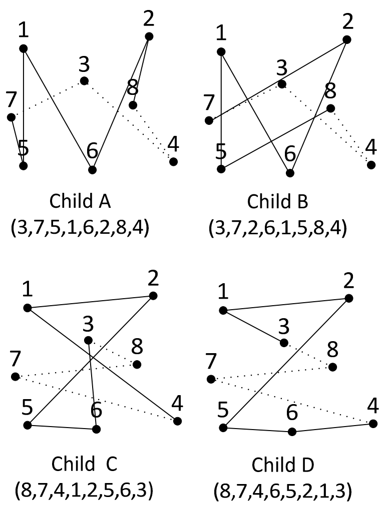

Figure 3: Relationship between sub tour and touring number

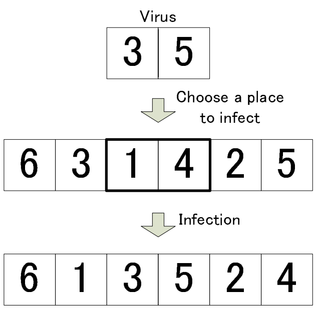

Figure 4: The mechanism of Infection.

4. Experimental Results

In order to confirm the performance of consideration of diverse solutions, we apply DS-GAVI to find approximate solutions in TSP such as att48 , eil51 and berlin52. In this study, $t_{max} = 5000$, $s = 5$, the number of simulation is 30 times, $U = 1000$, and *error rate* is defined by the following formula.

$$Error\ rate[\%] = \frac{(obtain) - (optimum)}{(optimum)} \times 100 \qquad (4)$$

where *obtain* is minimum solution and *optimum* is optimum solution. When *obtain* value approaches *optimum* value, *Error rate* is low. For example, when *obtain* value is equally *optimum* value, *Error rate* is 0[%]. If *Error rate* is 0[%], we would obtain optimum solution. However, if *obtain* is bad solution, *error rate* is high.

Table 1: The result of changing Selection rate in DS-GAVI

selection rate		Error rate[%]		
Good	Bad	att48	eil51	berlin52
1.0	0.0	1.222	4.148	0.209
0.8	0.2	1.140	2.026	**0.179**
0.7	0.3	1.649	**1.918**	0.277
0.6	0.4	**0.794**	1.984	0.308
0.5	0.5	1.536	2.461	0.955
0.4	0.6	1.485	2.142	2.915
0.3	0.7	1.649	6.746	7.587
0.2	0.8	3.498	39.896	17.259

Table 1 shows the result of average value and changing the both *Good Selection rate* and *Bad Selection rate*. *Good Selection rate* = 1.0 indicates only using Good Selection. We need to use properly parameter by each TSP type. However, we obtain better solutions than only using *Good Selection rate* = 1.0.

Whereat, Figs. 5-7 show the relationship between evaluation value in att48. Using parameters in DS-GAVI are *Good Selection rate* = 0.6 and *Bad Selection rate* = 0.4 in one simulation. In Figs. 5-7, we sort selected routes in descending order for facilitating visualization. Figures 5-7 show the results at $t = 0$, $t = 1000$ and $t = 4000$, respectively. In Fig. 5, the results of the both GAVI and DS-GAVI are almost same. While, in Figs. 6 and 7, the results of GAVI and DS-GAVI are different. Thus DS-GAVI is selected various evaluation value by the both Good Selection and Bad Selection in combination.

Table 2 shows the best result of each algorithm. In DS-GAVI, we use the best parameter in *Selection rate* by Table 1. For that reason it is efficient for escaping local minimum to keep diverse solutions. Thus, DS-GAVI can obtain the best result.

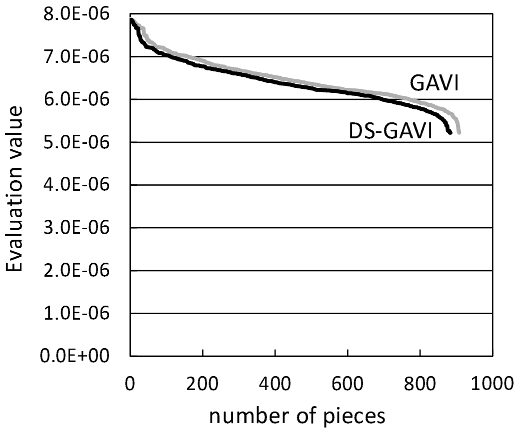

Figure 5: Relationship between evaluation value and selected routes at $t = 0$.

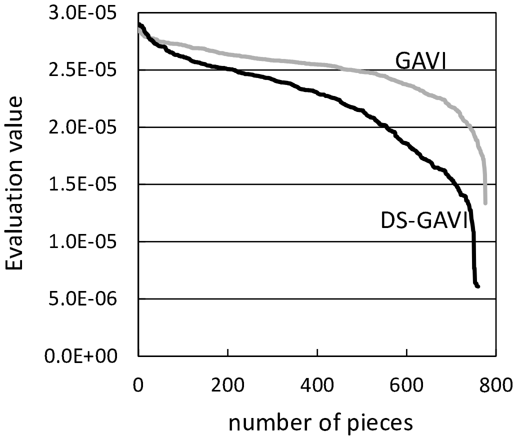

Figure 6: Relationship between evaluation value and selected routes at $t = 1000$.

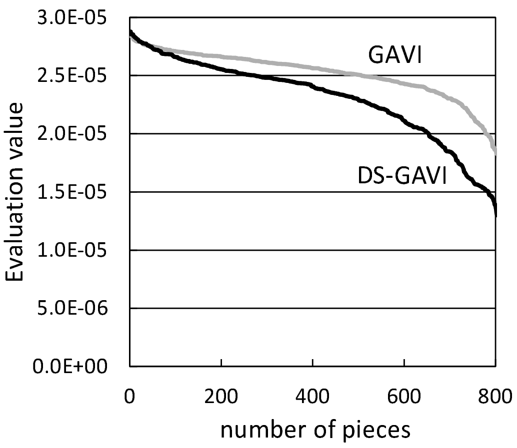

Figure 7: Relationship between evaluation value and selected routes at $t = 4000$.

Table 2: The best result of each algorithm for TSP

TSP type	Error rate[%]		
	GA	GAVI	DS-GAVI
att48	2.400	1.222	**0.794**
eil51	4.148	2.665	**1.918**
berlin52	0.787	0.209	**0.179**

5. Conclusions

We proposed DS-GAVI for TSP and compared the performance of GA, GAVI and DS-GAVI to lead approximate solutions. From the simulations, the result of DS-GAVI needs to use properly parameter by *Good Selection* and *Bad Selection rate*. In using the both Good Selection and Bad Selection in combination, DS-GAVI was able to keep diverse solutions. DS-GAVI was easier escaping local minimum than GAVI. Thus, DS-GAVI obtained better solutions than GAVI.

Acknowledgment

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