Combination of Immune Algorithm and Virus Theory of Evolution for TSPs

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Abstract—We propose Evolutionary Algorithm with Immune and Infection (EAI). EAI is using Virus Theory of Evolution algorithm to be based on Immune Algorithm. Thus, EAI finds an optimal solution in combinatorial optimization problems by updating antibodies and apart of the information of the antibody changing by Virus Theory of Evolution. We confirm that EAI obtains more effective result than others method.

I. INTRODUCTION

In daily life, there are many optimization problems. One of these optimization problems is Traveling Salesman Problem (TSP) [1]. TSP is known as one of combinatorial optimization problems when salesmen is given a set of number N cities. TSP is the problem of finding minimum total between each city distance. When the number of N increases, the total route number explodes. Therefore, exploring total route number needs amount of time in finding approximate solution. It is necessary to solve the TSP in other ways except exploring total routes. There is a variety of methods to find approximate solution by TSP [2]-[4].

Immune Algorithm (IA) [5], [6] is one of method to solve the TSP, and modeling behavior of updating antibodies in organism. In repeating these updating antibodies, antibodies group changes efficient group for fighting antigen. IA finds optimal solution by using these behavior.

However, IA considers only updating antibodies group. Thus, we focus attention on acquiring the Virus Theory of Evolution (VTE) by antigen besides updating antibodies group. We propose Evolutionary Algorithm with Immune and Infection (EAI1). EAI is using VTE algorithm to be based on Immune Algorithm. We confirm that the proposed algorithm achieves better performance than other methods.

II. VERSUS THEORY OF EVOLUTION

Organic evolution is theory based on natural selection. In 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 needs to overlay generations.

On the other hand, Virus Theory of Evolution (VTE) [7] has proposed aside from organic evolution. This theory is based on the evolution by Lateral Gene Transfer (LGT) [8] in Virus infection. 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. Algorithms of using VTE was proposed in the past [9]. We assume using VTE algorithm leads the approximate solution in less time and VTE theory is efficient in TSP.

III. EVOLUTIONARY ALGORITHM WITH IMMUNE AND INFECTION

In this section, we explain flow of Evolutionary Algorithm with Immune and Infection (EAI). Flow chart of EAI is shown in Fig. 1. Flow of EAI shows Steps 1-4. Step 2 from Step 4 is repeated until the set number of updating antibodies (tmax). t means the number of repeating times.

Step1 Initialization

We prepare a number of random route selection. We define the number of random routes as antibodies. The number of random route selection is U.
Step 2 Evaluation of antibodies

Where \( a x_i \) is level of affinity and is defined by the following Eq. (1). \( c a_j \) indicates the antigen, and \( N \) indicates number of city.

\[
ax_i = \sum_{j=1}^{N} ax_{ij}
\]  
(1)

\[
ax_{ij} = \begin{cases} 
1(c_{ij} = c_{aj}) \\
0(c_{ij} \neq c_{aj})
\end{cases}
\]  
(2)

Where \( c_i \) is concentration of specific antibody. \( S \) indicates number of antibody.

\[
c_i = \frac{1}{S} \sum_{j=1}^{S} ay_{ij}
\]  
(3)

\[
ay_{ij} = \begin{cases} 
1(ax_i = ax_j) \\
0(ax_i \neq ax_j)
\end{cases}
\]  
(4)

By using \( ax_i \) and \( c_i \), we calculate \( c_i \). \( d_{\text{total} - i} \) indicates total distance of each route. \( \alpha \) is coefficient. Where \( e_i \) is evaluation value, and is defined by the following Eq. (5).

\[
e_i = \frac{1}{(d_{\text{total} - i})^\alpha} \times \frac{ax_i}{c_i}
\]  
(5)

Equation (5) means that high evaluation values organism survive, while low evaluation values organism become extinct.

Step 3 Production of new antibodies

In surviving antibodies in Step 2, new antibodies is produced by Crossover and Mutation.

Step 4 Infection

We define elements of each route as antigen, elements select the minimum route in obtaining and part of each route is infected by this antigen at random. Number of element selects is fixed probability. Part of antibody changes the information held in this Virus like the Fig. 2. We call it Infection.

IV. Simulation Results

In order to compare the performance of EAI and other algorithms, we apply to find approximate solutions in TSP. In this study, the number of \( t \) is 2000 times, the number of simulation is 5 times, \( U \) is 1024, applying TSP are 4 kinds and error rate is defined by the following Eq. (6).

\[
\text{Error rate}[\%] = \frac{(\text{obtain}) - (\text{optimum})}{\text{(optimum)}} \times 100
\]  
(6)

where obtain shows obtained solution and optimum shows optimum solution.

Table I shows result of EAI, GA and ACO. GA is Genetic Algorithm [10], ACO is Ant Colony Optimization [11]. GA and ACO are same the number of \( t \) and \( U \) for comparing performance of EAI. In Table I, result of EAI is the best of three methods.

<table>
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<th>Algorithm</th>
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<th>gr120</th>
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</table>

V. Conclusion

We proposed EAI for TSP and compared the performance of EAI and other algorithms to lead approximate solutions. From the result, the result of EAI was better than other methods. Thus, it was efficient to use VTE based on IA in TSP. Furthermore, we expect that EAI has technological application possibility.

In future work, we would like to study the mechanism of Infection in detail. We expect to obtain a better solution by studying mechanism of Infection.

References