Immune algorithm for n-TSP

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ABSTRACT

As the neural networks or genetic algorithms, adaptive algorithms become so popular and these techniques are applied many kinds of optimization problems. The immune system is one of the adaptive biological system whose functions are to identify and to eliminate foreign material. In this paper, we propose an optimization algorithm based on immune model and applied to the n-th agents' travelling salesman problem called n-TSP. Some computer simulations are designed to investigate the performance of the immune algorithm. The results of simulations represent that the immune algorithm shows good performance for the combinatorial optimization problems.

1 Introduction

As the neural networks or genetic algorithms, adaptive problem solving techniques become so popular in the AI field and these techniques are applied many kinds of optimization problems. On the other hand, the immune system is widely recognized as one of the adaptive biological system whose functions are to identify and to eliminate foreign material. Research on the elucidation of this mechanism has just begun in the medical field.

In this paper, we propose an optimization algorithm based on the immune system. Specially, two memory mechanisms play an important part in the search efficiency of the algorithm. Furthermore, we applied this algorithm to the n-th agents' travelling salesman problem called n-TSP. Travelling salesman problem (TSP) is one of the most typical combinatrial optimization problem and the computational complexity is NP-hard. Recently, from the requirements of practical use, the definition of the number of salesman is extended from one to the plural number.

Some computer simulations are designed to investigate the performance of the immune algorithm. The results of simulations represent that the immune algorithm shows good performance for the n-TSP.

2 IMMUNE SYSTEM

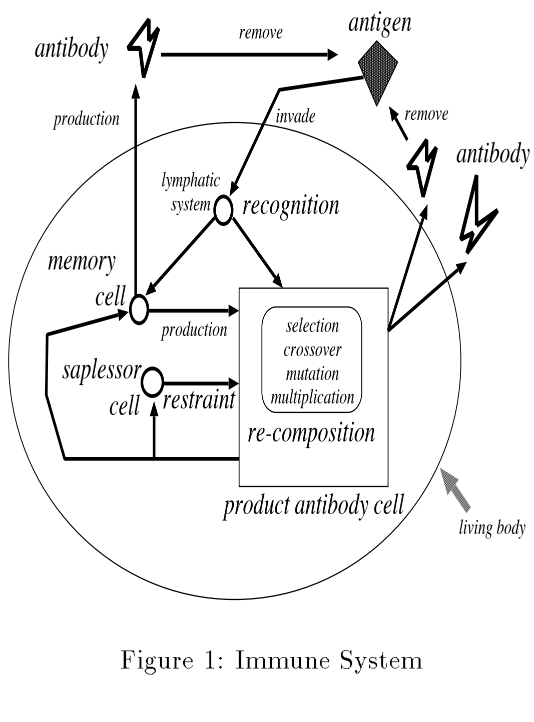

Figure 1: Immune System

The immune system illustrated on figure 1 consists of some functional subsystems. Some essential subsystems are antigen recognition system, memory mechanism, antibody production system and antibody restraint system. From the view point of engineering, this system is regarded as adaptive optimization system on the various kinds of dynamic environments.

3 IMMUNE ALGORITHM

3.1 BASIC ALGORITHM

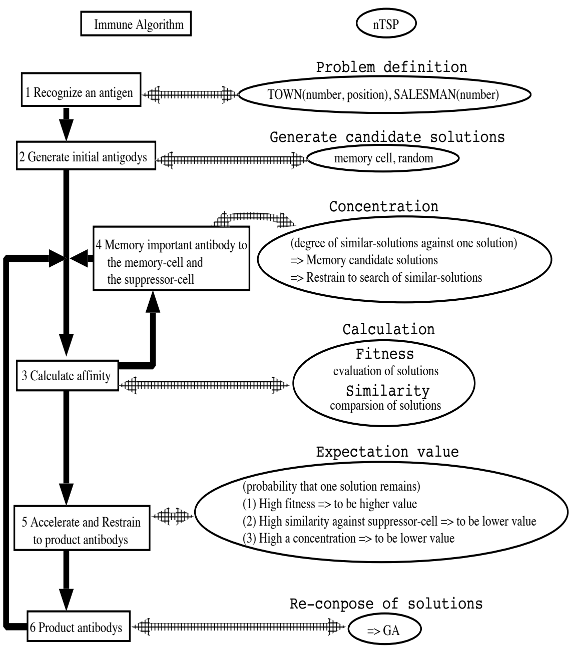

Figure 2: Basic algorithm

Each step of the basic algorithm and the relations of the correspondence with n-TSP are shown in the figure. 2. First step of this algorithm is to initialize the problem environment. Second step is to generate some candidate solutions. Third is to calculate evaluation value (like GA) and similarity value of each solution. Fourth is to memory some important solutions on suppressor cell and memory cell. The memory on suppressor cell are used to change search scope effectivly and the memory on memory cell are used to keep the candidate solutions. Fifth is to modify the fitness landscape based on the similarity value of each solution. Sixth is to reproduce candidate solutions using GA. Accordingly, immune algorithm is considered as the improvement of genetic search technique.

3.2 CHARACTERISTICS

As it is shown in the figure3, it can think about immune algorithm with the improvement of GA. Especially, it is the expansion point that two memory mechanisms, that is, a memory cell and suppressor cell against GA. However, there are some problems.

- The reproduction of candidate solutions is done only with the GA operators, and it doesn't use the multiplication mechanism which the immune system has specifically.
- When the similar problems are solved, the memory acquired in the past isn't used at all.

So, we introduce the method of using a new memory mechanism in the algorithm.

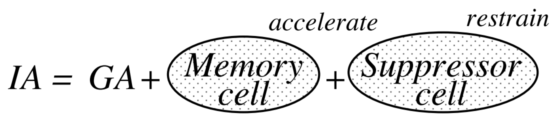

Figure 3: Relations between GA and IA

3.3 EXTENDED ALGORITHM WITH MEMORY FUNCTIONS

The algorithm that two new memory mechanisms were expanded is shown in the figure4.

In the step 4 of the figure4, the concentration of all the candidate solution of is calculated, and the memory of the candidate who exceeded a threshold is done. At this time, if it is usual search phase, it proceeds to the step 4-1 and it proceeds to the step 4-2 if it is phase of the local search.

3.3.1 PRIMARY MEMORY MECHANISM

By the primary memory mechanism of the step 4-1, the common characteristics of the candidate group are memorized as a template in the memory cell. An candidate group is reproduced based on that template, and a local search is accelerated.

3.3.2 SECONDERY MEMORY MECHANISM

By the secondery memory mechanism of the step 4-2, the candidate solution who has maximum concen-

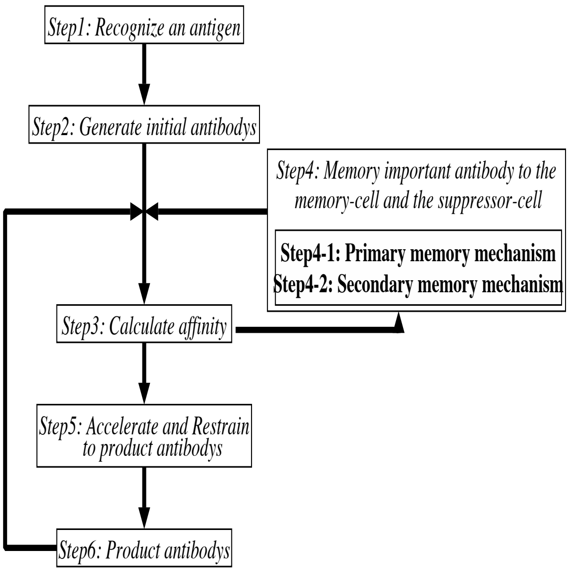

Figure 4: Immune algorithm with memory mechanism

tration in the candidate group is memorized in suppressor cell. Increase in the candidate solutions memorized in suppressor cell are restrained.

3.4 PROCESSES

The process of two memory mechanisms is shown in the figure7.

The refinement of the candidate solutions by acceleration of the local search and the proper shift of the search scope are carried out by these mechanisms.

4 IA FOR n-TSP

4.1 PROBLEM DEFINITION

To investigate the performance of immune algorithm, we adopt the travering salesman problem. One of the reason to adopt TSP is that TSP provides two peaks deceptive problem. In this deceptive problem, each city is arranged on two-fold concentric circles. Two kinds of problems can be made by changing two circular radius ratios. As for one problem, C-type of the figure8 is the answer which it is the most suitable for, and O-type is the answer which it is the most suitable for as for the other problem.

Fitness landscape of the deceptive problem is shown in the figure9. In immune algorithm, a local search

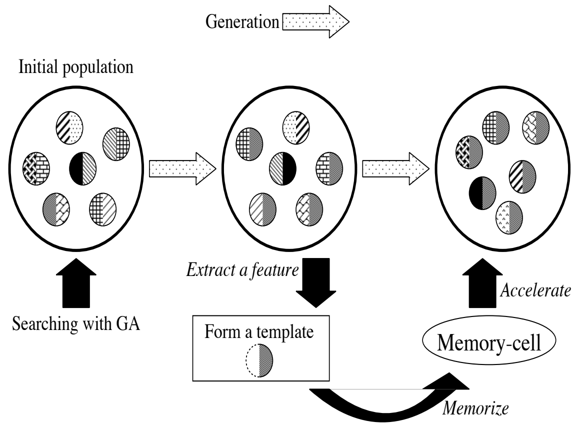

Figure 5: Primary memory mechanism

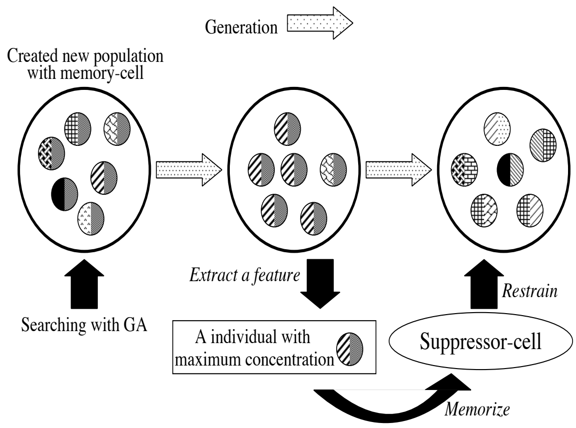

Figure 6: Secondary memory mechanism

around one peak is made intensive, and a nearby search is restrained after that. In other words, the fitness value of landscape which searched it once is lowered. From this reason, effective search can be expected.

4.2 DESIGN OF IA

4.2.1 CORDING AND OPERATORS

The candidate solutions must be encoded, like GA, in the strings to apply immune algorithm to n-TSP. We adopted the pass representation method originally proposed by Yamamura[6]. This reason is because the pattern match to calculate a degree of similarity is easy. Then, expansion to the n-agents, is realized by

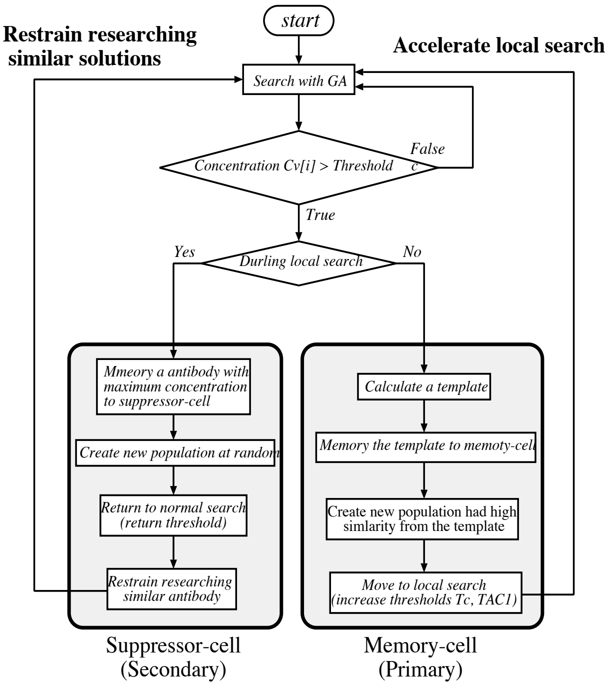

Figure 7: Process of memory mechanism

adding partitioning data to the strings. Furthermore, subtour crossover corresponding to the pass representation method is adopted. In subtour crossover, two subtours which have the same elements are looked up, and those subtours are replaced. It becomes possible that the destruction of the important subtour is prevented by adopting this method. Subtour crossover is shown in the figure10.

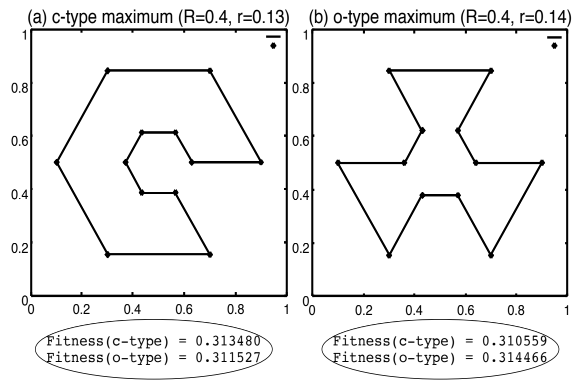

Figure 8: c-type and o-type

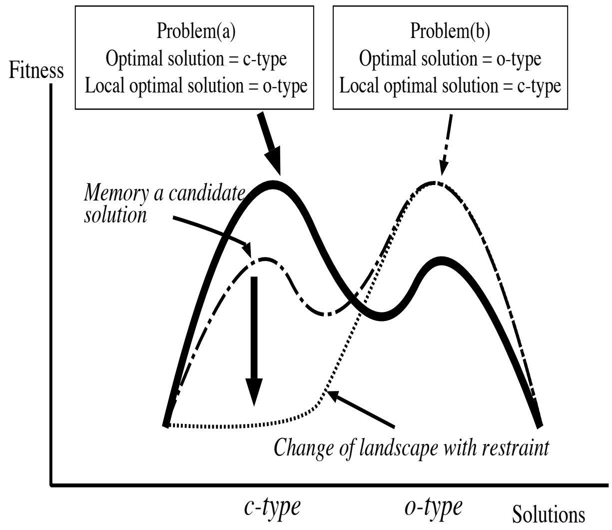

Figure 9: Fitness-landscape of similar problem

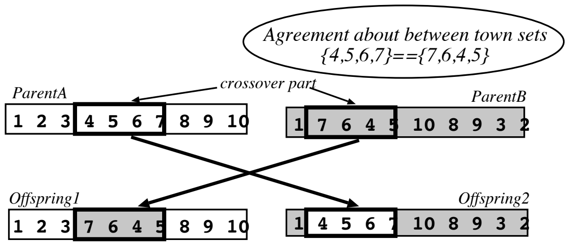

Figure 10: Subtour crossover

4.2.2 FUNCTIONS

Four evaluation measures are used with the immune algorithm. They are fitness, similarity, concentration and expectation value. These equations are shown in the following.

fitness

$$fitness_i = 1/(Cost * Cost_W + Penalty * Penalty_W) \quad (1)$$

$Cost : \sum f_d(P_{S_i})$
$Cost_W : weightofCost$
$Penalty : penaltyfortheequality$
$Penalty_W : weightofpenalty$

similarity

$$ay_{v,\,w} = (numberofcitiesincommonroute)/m \quad (2)$$

concentration

$$c_v = (numberthatsimilraityexceededTac1)/pop\_size \quad (3)$$

expectation value

$$e_v = fitness_i \times (1 - ay_{v,\,s}) \tag{4}$$

$ay_{v,\,s}$: $similaritywiththeantibodyvandsurpcell$

5 EXPERIMENTS

5.1 DEFINITION OF EXPERIMENT 1

Deceptive problem of n-TSP is used to verify the validity of the memory mechanism of the proposed algorithm. If the refinement of the local solutions by the memory mechanism is satisfactory, the template which shows the characteristics of O-type or C-type is supposed to be kept in the memory cell. And, if the proper shift of the search scope is made, both characteristics of O-type and C-type are supposed to be kept in the memory cell. The definitions of the problem and using parameters are shown in the following table.

Table 1: Problem definition

optimal type	c-type
number of cities	12
radius of the outside circle	0.40
radius of the inside circle	0.13
generations	2000

Table 2: IA parameter

population number	100
crossover rate	1.0
mutation rate	0.01
memory cell number	10
suppressor cell number	5
TC	0.6 (0.66)
$TAC1$	0.6 (0.66)
$TAC2$	0.7
TC_{power}	1.1
$MemoryT$	0.7

5.2 RESULTS AND DISCUSSIONS

The contents of the memory cell are shown in the figure11. And, the number of each generation that the optimal solution, local maximum and each memory could obtain is shown in the table3.

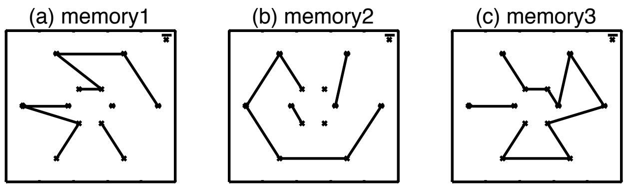

Figure 11: Obtained memory

Table 3: Generation obtained memorys and solutions

memory cell 1	468
memory cell 2	883
memory cell 3	1323
local maximum (o-type)	53
optimul (c-type)	760

In the figure of memory111, the characteristics of the problem aren't acquired with the memory of early generation. On the other hand, memory2 shows the characteristics of C-type, and memory3 shows the characteristics of O-type. And, these two characteristics are acquired by the execution of one time. From these results, it can be said that the proposed algorithm functions effectively.

5.3 DEFINITION OF EXPERIMENT 2

In this experiment, it is examined about the efficiency of our algorithm when the past memory is used toward the similar problems. It is compared about the following three kinds of cases.

case1 No memory is used.

case2 The memory of solving a C-type problem is used.

case3 The memory of solving a O-type problem is used.

The local mimimum solution and the optimal solution of this experiment are shown in the figure12. The definition of the problem is shown in the table4. And, a parameter is the same as the experiment 1.

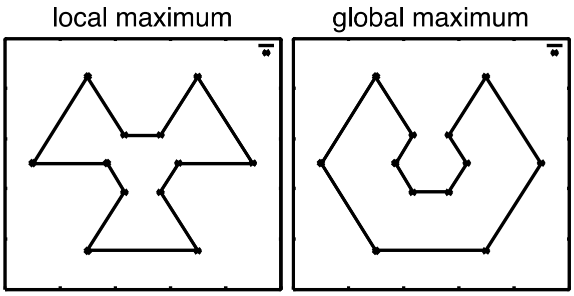

Figure 12: Local optimal solution and optimal solution

Table 4: Problem definition

parameter	c-type	c'-type	o-type
number of cities	12	12	12
radius of the outside circle	0.4	0.4	0.4
radius of the inside circle	0.13	0.131	0.14
generations	2000	2000	2000

5.4 RESULTS AND DISCUSSIONS

The comparison of the search efficiency is shown in the figure13. The fitness value of the initial group of the search which the memory was used for is high in comparison with the case that memory isn't used. Therefore, the efficiency of the search improves.

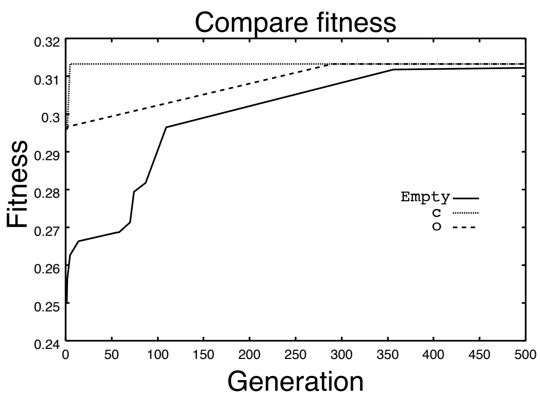

Figure 13: Compare efficiency

The number of generations of each search to the optimal solution acquisition is shown in the table5.

Table 5: Generation obtained oprimal solution

probrems	empty	c-memory	o-memory
generation	882	228	290

6 CONCLUSION

In this paper, we proposed the immune algorithm as one of the adaptive optimization algorithm. Furthermore, two memory mechanisms were introduced, and search efficiency improved. This algorithm was applied to n-TSP, and validity was examined. As the results of the experiments, it confirmed that the search efficiency improved by a memory mechanism's working effectively.

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