An Algorithm Based on Antibody Immunodominance for TSP

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Abstract. A new algorithm based on antibody immunodominance (AIDA) for TSP is explored. The main content of this paper is to explore how to produce the set of immunodominance and the superior antibodies. The experience proves that the algorithm has higher convergence speed and better solution compared with the corresponding genetic algorithm and is fit to solving complex problems.

1 Introduction

The traveling salesman problem (TSP) can be stated very simply: A salesman visits n cities (or nodes) cyclically. In one tour he visits each city just once, and finishes up where he started. In what order should he visit them to minimize the distance traveled? It is one of the typical and most widely-studied problems [1]. Immunity algorithm is a novel algorithm based on the theory of biological system [2] [3], and is more effective than GAs in some cases.

This paper proposed an immunity algorithm based on antibody immunodominance. First, an immunodominance set is formed based on the basic knowledge of the problem; the antibodies those gain the immunodominance by this set become superior ones. Second，strengthen these superior antibodies. Gradually, the algorithm will converge to the optimal answer (or satisfactory answer).

2 Algorithm Based on Antibody Immunodominance

2.1 Immunodominance

By the theory of immunology [4], there are many epistasises on an antigen, but only one epistasis works when the immunity respond takes place. This phenomenon is called immunodominance. Immunodominance was the product of the operation between antibody and antigen. Its produce and operation are both dynamic processes.

This work denotes the different significance of every section of the code of antibody by the definition of the immunodominance. So the principle of the antibody

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immunodominance is determining some section of the antibody to decrease the range of the search, moreover, developing the performance of the algorithm. An antibody immunodominance operator for TSP (TSP-AIDO) is proposed in the following**.**

2.2 Antibody Immunodominance Operator

Commonly, in immunity algorithm for TSP an antibody expresses an answer:

$$\boldsymbol{a} = \pi(\boldsymbol{X} = \{v_1, v_2, \cdots, v_n\}) \tag{1}$$

Antigen corresponds to the object function and the affinity between antibody and antigen is determined by the distance of the corresponding path.

$\boldsymbol{ID} = \{(d_i, v_i, v_j)\}$ is defined as the basic immunodominance set, $v_i \in \boldsymbol{e}_1 \subset \boldsymbol{a}$, $v_j \in \boldsymbol{e}_2 \subset \boldsymbol{a}$, $\boldsymbol{e}_1$, $\boldsymbol{e}_2$ are the two subset of $\boldsymbol{a}$, usually, $\boldsymbol{e}_1 \cap \boldsymbol{e}_2 = \Phi$, d_i, v_i, v_j satisfies the require:

$$d_i = \min(d(v_i, v_j)) \qquad v_i \in \boldsymbol{e}_1, v_j \in \boldsymbol{e}_2 \tag{2}$$

v_i, v_j are called the immunodominance sections of the antibody. On the assumption that $\boldsymbol{a} \in \boldsymbol{A}$, $i = 1,2,\cdots,m$ is an antibody, if the $\boldsymbol{k^{th}}$ position is to be changed, it must follow the basic immunodominance rules in certain way; this process is called immunodominance obtainment. The immunodominance operator is illustrated as Fig 1.

TSP Antibody Immunodominance Operator (TSP-AIDO)
Begin:
while($\boldsymbol{e}_1 \neq \Phi$)do
{ $\boldsymbol{ID} = \{(d_i, v_i, v_j)\}$, $d_i = \min(d(v_i, v_j))$, $v_i \in \boldsymbol{e}_1, v_j \in \boldsymbol{e}_2$;
Put v_i behind v_j;
Remove v_i from $\boldsymbol{e}_1$;}

Fig. 1. Immunodominance Operator

TSP Antibody Immunodominance Algorithm(TSP-AIDA)
Begin:
Initialize population $\boldsymbol{p}$;
Estimate the affinity between antibody and antigen;
While(**not** termination condition)do
{Form immunodominance set *ID* based on the knowledge of the problem;
Get immunodominance to produce $\boldsymbol{qt}$;
Immunity selection: if affinity $_{qt}$ > affinity $_{p_{(\min)}}$ ($\boldsymbol{p}_{(\min)}$ express the antibody with minimal affinity);
{ $\boldsymbol{qt}$ substitute for $\boldsymbol{p}_{(\min)}$;}
inverse operator; } // local search

Fig. 2. Process of the algorithm

2.3 Process of the Algorithm

The process of TSP antibody immunodominance algorithm (TSP-AIDA) is illustrated in Fig 2.The affinity between antibody and antigen is corresponding to the fitness in GA The code method and inverse operator are as same as those in GA.

The TSP-AIDO is similar to the crossover operator in GA, but there are essential differences between them. TSP-AIDO is not simply exchanging the section of the antibodies as the crossover operator in GA but forming and obtaining immunodominance based on the different significant of every position of the antibody.

3 Validity of TSP-AIDA's Effectiveness

In order to test the performance of the algorithm, gridding, circle problems and benchmark problems [5] were tested in this paper. The method was implemented on a Pentium IV 2.4 GHz personal computer with a single processor and 1 GB RAM.

TSP-AIDA is compared to an improved GA which is called NGA in this paper. The crossover operator of NGA is "similar OX" that is said to be better than conventional ones in reference [6].

In the first part, the known optimal solutions are found by TSP-AIDA every time of 10-time independent test. The results is illustrated in table 2, in which, n expresses the number of the "cities" and S_0 expresses the known optimal solution.

Table 2. Test result 1

Problem	n	S_0	algorithm	time spent on getting the optimum (CPU time) (s)		The minimal distance	
				Min	Mean	Min	Mean
Gridding TSP*	36	6.0000	NGA	/	/	6.1381	6.1934
			TSP-AIDA	433.5	769.7	6.0000	6.0000
Circle TSP*	100	62.8215	NGA	/	/	69.0863	70.3446
			TSP-AIDA	1032.7	1189.7	62.8215	62.8215
Pa561	561	19330.8	NGA	20.4	23.0	16558.14	16674.70
			TSP-AIDA	12.5	14.4	15739.69	16146.23
Gr666	666	3952.54	NGA	25.4	32.5	3321.1	3416.7
			TSP-AIDA	8.5	11.0	3200.6	3275.3

Note: 1.the problems those are marked with * are tested with the programming language MATLAB6.5 and the others with VC++6.0
2. In terms of some problems, NGA can't find the optimal solutions of them every time, so the time is unable to be measured; they are expressed by / in the table.

In the second part, TSP-AIDA can't find the known optimal solutions every time, but it is still superior to the corresponding NGA. The test results are shown in table 3.

Table 4. Test result 2

problem	n	S_0	algorithm	The minimal distance		σ (%)
				min	mean	
Pcb442	442	5078.35	NGA	5657.77	5705.79	12.36
			TSP-AIDA	5184.49	5278.40	3.94
Pr1002	1002	259068	NGA	286740	288010	11.17
			TSP-AIDA	269343	269355	3.97
Pr2392	2392	378063	NGA	427515	431036	14.01
			TSP-AIDA	409779	415130	9.80

Note: 1.all the problems are tested with programming language VC++6.0

2. $\sigma = \sum_{i=1}^{10}(S_{Ti} - S_0)/10S_0 \times 100\%$ S_{Ti} expresses the minimal distance gotten in the first part test.

4 Conclusions

In this paper, we proposed a novel immunity algorithm for TSP, which is named TSP-AIDA. TSP is a NP-hard problem, with the augment of the number of the "cities", the amount of the local optimal solutions has an exponential increase, TSP-AIDA can't find the optimal solution of some problems(n>1000,usually) every time, although it is better than the corresponding GA. One hand, it is because the common currency of the algorithm is considered in this paper, another hand, the performance of the algorithm is related to the parameters, the size of the population, for example. Improving the algorithm's performance and extending it to other optimization problems are our future work.

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