A GENETIC ALGORITHM BY USE OF VIRUS EVOLUTIONARY THEORY FOR SCHEDULING PROBLEM

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ABSTRACT

The genetic algorithm that simulates the virus evolutionary theory has been developed applying to combinatorial optimization problems. The algorithm in this study uses only one individual and a population of viruses. The individual is attacked, infected and improved by the viruses. The viruses are composed of four genes (a pair of top gene and a pair of tail gene). If the individual is improved by the attacking, the infection occurs. After the infection, the tail genes are mutated. If the same virus attacks several times and fails to infect, the top genes of the virus are mutated. By this mutation, the individual can be improved effectively. In addition, the influence of the immunologic mechanism on evolution is simulated.

1 INTRODUCTION

Nowadays several evolutionary theories are proposed in biology. The virus evolutionary theory is one of them (Anderson,N,1970). The virus evolutionary theory locates evolution of life as epidemic caused by viruses. It describes that the evolution occurs by virus infection and reconstruction of gene of individual. According to the virus evolutionary theory, life has a new ability, the shape is changed and the existing ability is lost.

A genetic algorithm (GA) that simulates the evolutionary theory by virus infection (GAV) is developed and tested applying to a combinatorial job-shop scheduling problem (JSSP) in this study.

A standard GA is a simulation based on the mechanism of natural selection that is the evolutionary theory of Darwin. The standard GA is carried out generating a number of individuals (chromosomes) and selection, crossover and mutation of them are the main procedure for the algorithm. On the other hand, GAV developed in this study uses only one individual and a population of viruses. The individual (chromosome) is attacked and infected by the viruses and the individual is improved without using the selection and the crossover and so on.

In this paper, the validity of GAV and the effectiveness of the mutation of the viruses and an antibody (immune function) of the individual are investigated applying to combinatorial problems.

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2 THE VIRUS EVOLUTIONARY THEORY

Imanishi evolutionary theory (Harstead,B, 1985) discusses that the evolution of species occurs drastically in a short period (horizontal evolution) after keeping its characteristics for relatively long period. It is discussed by the virus evolutionary theory that the mechanism of Imanishi evolutionary theory can be explained by the virus evolutionary theory.

The virus evolutionary theory in biology is the one assuming that the gene of virus or transposon of other individual is buried on the chromosome of individual by the virus and bacillus and sometimes the peaceful and rapid horizontal evolution is caused in a short period.

The method developed in this study uses the conception of horizontal evolution by Imanishi theory and it uses the idea that the evolution occurs by virus infection. In this case, the selection among many individuals is not necessary. Therefore only one individual (Chromosome) is used in this algorithm.

3 ALGORITHM OF GAV

3.1 Chromosome for Job-Shop Scheduling problem

In this study, the famous job-shop problem (Muth & Thomson's problem Table 1) is used as the simulation of GAV.

Table 1 Job-shop problem

(Muth and Thompson, 1963)

Job	Machine	Optimum value
6	6	55
10	10	930
20	5	1165

The chromosome (individual) is basically expressed by the row of a couple of gene that are Job number and the order of processing as shown in Fig.1. Fig.1 shows the case of 6 jobs and 6 machines. The upper row is made of the number of 1 ~ 6. Each number indicates the job number. Therefore there are 36 figures from 1 to 6 for 6 jobs and 6 machines. The scheduling (Gantt chart) is determined in order of these numbers. The numbers of the lower raw show the occurrences count of the same job that is the order of processing of the same job. These pairs of the numbers are the genes of the chromosome.

3.2 The Genes of Virus

The viruses are composed of two parts, top genes and tail genes as shown in Fig.2. Top genes are expressed by the gene (JOB) which is the job number and gene (NUM) which is the number of the order of processing. Tail genes are similarly expressed. If the virus in Fig.2 attacks the individual in Fig.3, the screened genes showed in Fig.3 are attacked.

Two ways of the infection are tried. One is the insert method and another is the exchange method.

The insert method is to insert the gene of the chromosome corresponding to the tail genes after the gene of the chromosome corresponding to the top genes. The virus attacks to the gene of the individual that is matched to the top gene of the virus. If the individual is improved by the attacking, the infection occurs by embedding the tail genes after the attacked gene and removing the corresponding genes from the string of the chromosome.

Job number	3	1	4	2	6	5	5	3	3	4	6	2	1	1	..
Number of order of processing	1	1	1	1	1	1	2	2	3	2	2	2	2	3	..

Fig.1 The chromosome for the job-shop problem

	JOB	NUM	
Top	3	1	
Tail	4	3	

Fig.2 A example of genes of virus

Usually, genotype of chromosomes is used for the standard GA and therefore the encoding is rather difficult requiring the special technique.

On the other hand, phenotype of chromosome can be used in this scheme. Therefore, the encoding of the chromosome for the GAV is easy.

The exchange method is a method of exchanging the genes specified with top genes and tail genes. If the individual is improved by the attacking, the infection occurs. After the infection, the tail genes are mutated. If the same virus attacks several times and fails to infect, the top genes of the virus are mutated. The mutation of the viruses is very important for the improvement of individual. By these procedures, the viruses attack effectively i.e. the individual is improved effectively.

The solution by the procedure stated above falls easily into local minimum as other search methods. To avoid the local minimum, the allowance of the infection is set i.e. the infection that makes the individual worse in a small amount is admitted in a small provability as well. By this procedure, it reaches to the acceptable or satisfactory solution easily though it may not be the optimum solution. One of the examples of the simulation procedure is described below.

Job number	1	2	5	4	3	5	6	6	4	1	2	4	3	• • • • •
Order of processing	1	1	1	1	1	2	1	2	2	2	2	3	2	• • • • •

Fig.3 Attack of the virus to the chromosome

Start;
The generation of the individual;
The generation of the population of the viruses;
Repeat until the satisfactory solution is reached;
Attacking of the virus;
Evaluation of the objective function;
if evaluation becomes higher
{Infection of virus;}
else, if the evaluation value is less than (1+AR) times the previous one in a small probability below PR,
{Infection of the virus;
Mutation of the tail gene of the virus;}
else, if the attack of the same virus fails to infect over several times
{Mutation of the top gene;}
End of repeat;
End.

Where AR is the allowance rate and the infection that lower the evaluation value by (1+AR) times is admitted. PR is the probability rate and AR is applied in a probability below PR.

The phenotype can be used and the programming of this algorithm is simple as compared with the standard GA. This method (GAV) can be applied to solve combinatorial optimization problems such as traveling salesman problem, facilities location problem, vehicle routing problem and so on without difficulty. In this report, application to job-shop problem is described.

3.3 Result of GAV

Fig.4 shows the time series data of the evaluation value. The present value becomes worse sometimes than the best value that is the best one obtained at that time. This is because the allowance is set.

Fig.5 shows the Gantt chart of 10 jobs and 10 machines derived by GAV

As for the 6 jobs and 6 machines, the optimum solution can be obtained easily. Table 2 shows the results of 10 jobs and 10 machines obtained by GAV of exchange method. Although it failed to obtain the optimum value (930) by this method, it is considered that the better value can be obtained as compared with result obtained by standard GA.

8→1% for AR in table 2 means that the value of AR changes from 8% to 1% as the evaluation value becomes

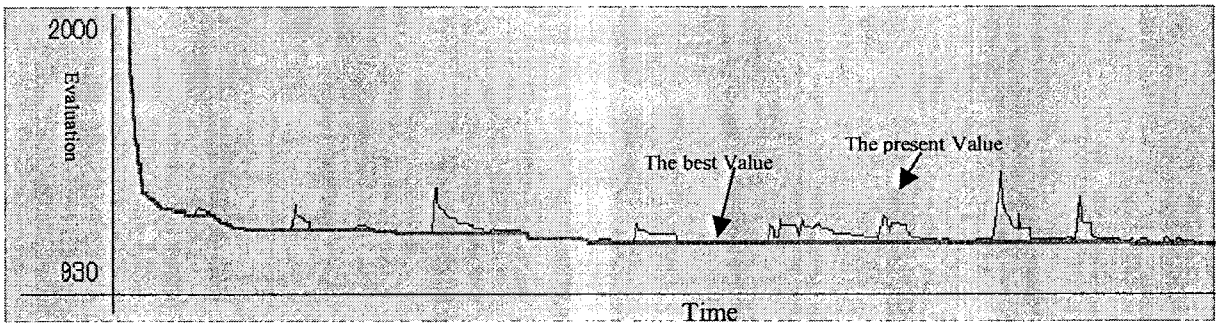

Fig.4 Time series of the evaluation value (AR=3%, PR=1%)

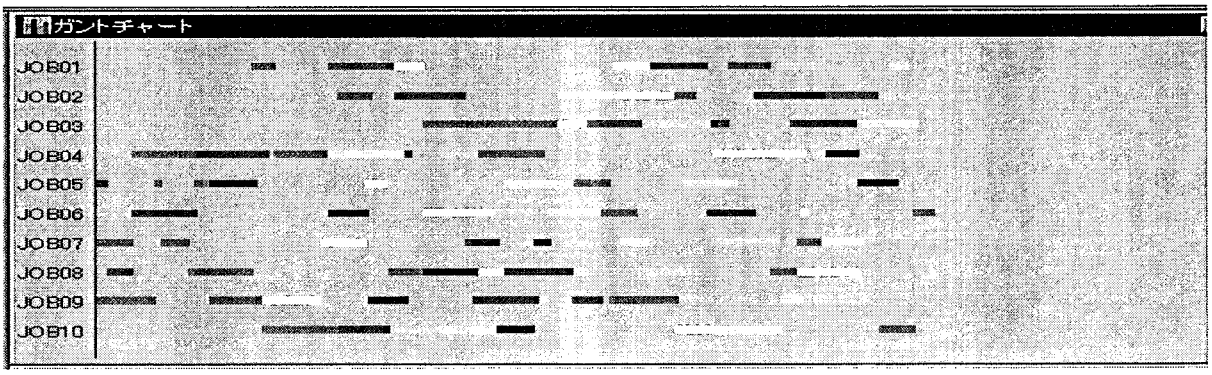

Fig.5 The Gantt chart of 10 jobs and 10 machines

better. 1→8% for PR means that the value of PR increases as the evaluation value increases.
The setting that AR decreases and the PR increase according to the evaluation value showed the best result in the simulation (screened cells in table 2). AR 1→8% and PR 8→1% that is an opposite pattern shows good result in the same way as average 998.7 and standard deviation 19.3. That is to say, the chance of infection (PR) should be increased instead of reducing AR as approaching optimum value or it is necessary to decrease the chance of infection (PR) in case of decreasing AR instead.

If the insert method is used, all following antibodies from the burial position are deleted. Therefore the exchange method is used in this scheme.

4.2 Results of GAV with the Immunologic Mechanism

Table 3.shows the results of GAV with the immunologic mechanism (10 jobs, 10 machines). Though a good result was expected, it was not better result than GAV without the immunologic mechanism. This process is rather complicated as compared with the usual GAV. Therefore it is not efficient in computer simulation, which is processed sequentially. It is considered that the better result can be obtained by improving the attack of the virus in GAV with the immunologic mechanism.

In the natural world, the attack of viruses and generation of antibody are processed in parallel. Therefore it cannot be asserted that the immunity is not related in evolution.

Table 2 Results by GAV (10 Jobs, 10 Machines)

	1	2	3	4	5	6	7	8	9	10
AR	8→1%	8→1%	1→8%	1→8%	1→8%	8→1%	1%	8%	1%	8%
PR	1→8%	8→1%	1→8%	8→1%	4%	4%	1%	8%	8%	1%
The best value	937	977	971	971	968	975	1001	1021	999	981
Average value	971.6	1013	1009.7	998.7	1005.5	1005.2	1026	1047	1031	1020
Standard deviation	18.787	18.508	21.477	19.306	28.506	19.922	16.581	21.074	18.869	35.716

4 GAV WITH THE IMMUNOLOGIC MECHANISM

4.1 Algorithm

It is tried to investigate the influence of immunity(antibody) on evolution of individual. Fig.6 shows the explanation of GAV with immunologic mechanism. The antibody value is given to the gene of chromosome. As this antibody is one related to the connection of the genomic location and Job number, the antibody value returns to 0 when the position of Job changes as shown in Fig.6(a). The antibody value is enlarged when the infection of the virus does not succeeded (Fig.6(b)).

The virus searches the gene that can be attacked while avoiding this antibody and attacks the gene that does not have the antibody (Fig.6(b)). This process is for the virus to attack the chromosome effectively.

A strong virus that disregards the antibody is made to appear sometimes also. This is to keep the variety of the gene change and to avoid the local minimum.

The cording of the virus is similar to usual GAV. The top gene and the tail gene have the attack destination and the replacement gene information respectively.

5 CONCLUSIONS

The algorithm that simulates the virus evolutionary theory has been developed applying to combinatorial problem.

Usually, genotype of chromosomes is used for the algorithm in standard GA and therefore the encoding is rather difficult requiring the special technique. On the other hand phenotype of chromosome can be used in this scheme of GAV. Therefore, the encoding of the chromosome for the GAV is easy.

The process to admit the allowance for the infection of virus in a small probability is useful to escape from the local minimum. The mutation of viruses is very important for the evolution in GAV.

This simulation shows the comparatively good results in applying to the combinatorial problems.

The simulation of GAV that is given the immunologic mechanism does not show a favorable result for the evolu-

tion as compared with the usual GAV. However, it is considered that GAV with the immunologic mechanism shows good results by improving the method of attacking of the viruses.

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Virus before attack			
	JOB	NUM	Insert position
Top	3	2	Search
Tail	1	1	Search

Chromosome (individual) before it is attacked																		
JOB	2	3	1	4	5	3	2	4	4	4	3	2	5	6	6	5	1	··
Occurrence number	1	1	1	1	1	2	2	2	3	4	3	3	2	1	2	3	2	··
Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	··
Antibody	3	3	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	··

Mutated virus after attack			
	JOB	NUM	Insert position
Top	3	2	Search
Tail	x	x	Search

Chromosome (Infected)																		
JOB	2	3	3	4	5	1	2	4	4	4	3	2	5	6	6	5	1	··
Occurrence number	1	1	2	1	1	1	2	2	3	4	3	3	2	1	2	3	2	··
Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	··
Antibody	3	3	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	··

(a) Case that the infection succeeded

Virus before attack			
	JOB	NUM	Insert position
TOP	3	2	Search
TAIL	1	1	Search

Chromosome (individual) before it is attacked																		
JOB	2	3	1	4	5	3	2	4	4	4	3	2	5	6	6	5	1	··
Occurrence number	1	1	1	1	1	2	2	2	3	4	3	3	2	1	2	3	2	··
Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	··
Antibody	3	3	3	3	3	2	0	0	0	0	0	0	0	0	0	0	0	··

Mutated virus after attack			
	JOB	NUM	Insert position
TOP	2	2	Search
TAIL	x	x	Search

Chromosome(not infected)																		
JOB	2	3	1	4	5	3	2	4	4	4	3	2	5	6	6	5	1	··
Occurrence number	1	1	1	1	1	2	2	2	3	4	3	3	2	1	2	3	2	··
Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	··
Antibody	3	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	··

(b) Case that the infection failed

Fig.6 The genes of Virus and individual for the immunologic mechanism

Table 3 Results by GAV with the immunologic mechanism (10 Jobs, 10 Machines)

Random rate of selection of virus	0%	25%	50%	75%
MIN	1028	1020	1006	1024
average	1043.2	1026.2	1023.4	1061.6
Standard deviation	10.107423	4.2614552	21.666564	35.251099

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