UNIVERSITY TIMETABLING IN MINIMUM AREA OF CLASSROOM USING EVOLUTIONARY COMPUTATION BY VIRUS EVOLUTIONARY THEORY

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Abstract

A genetic algorithm using a virus evolutionary theory (GAV) was developed and applied to a class schedule.
The minimum number and area of classrooms for classes conducted in the six undergraduate school departments and the three graduate school departments in the faculty of science in our university were sought and it is tried to obtain the most efficient class schedule for them. The maximum number of subjects is 640.
The class schedule was created by GAV under the condition of the minimum number and area of classrooms and that of well-balanced required subjects. GAV was carried out by attacking a chromosome by a number of viruses. The genes of the chromosome were recombined by the attack. The infection was admitted when the evaluation value went up, but it fell into local minima immediately. In order to escape from these local minima, an infection which made the evaluation value worse in a small rate (AR) under a low probability (PR) was recognized as well. In this case, AR and PR were made smaller as the evaluation value went up, whereby it escaped from the local minima and optimum condition was obtained. The parameters for AR and PR are very important to obtain the optimum solutions and the best parameters were sought. The main purpose of this study is to obtain the data of the minimum number and area of classrooms for the construction of the new building. For this aim, this method is useful.

Keywords: Virus Evolutionary Theory, Class Scheduling, Combinatorial Optimization

Presenting Author's biography

Susumu Saito is a Professor of School of Management, Tokyo University of Science. He received B.S. from Tokyo University of Science and Dr. of Engineering from Keio University.
His research interests are in production engineering, combinatorial optimization and simulation of economical time series.
He is a member of ORSJ, IPSJ, SICE, JFPS, and JSME.

1 Introduction

A genetic algorithm is a method used for combinatorial problems, and it is based on the theory of evolution by Darwin. Some suggestions have been made for the theory of evolution currently, and the virus evolutionary theory is one of them. This laboratory has so far developed a genetic algorithm using the virus evolutionary theory, and applied it to a variety of combinatorial problems [1][2]. The standard genetic algorithm has used a number of chromosomes (individual), and an individual with high evaluation value is sought by selection, crossover and mutation. In the meanwhile, the genetic algorithm using the virus evolutionary theory developed in this study is a method where improvement for an individual is carried out by attacking and infecting with a number of viruses.

Timetabling attracts researchers as interesting combinatorial problem [3] - [5]. But the scheduling under the condition of the minimum number and area of classrooms for classes has not been seen.

Currently, in this university, a plan of turning an old building into a new one is being advanced. In this case, it is beneficial to design classrooms as small as possible. Here, the minimum number and area of classrooms for classes conducted in the six undergraduate school departments and the three graduate school departments in the faculty of science were sought, and it was tried to obtain the most efficient class schedule for them. The maximum number of subjects was 640 in this case.

The main object of this study is to carry out the scheduling in the minimum number and area of classrooms. If the constraint of the classrooms does not exist, the problem will become much easier.

2 The conditions of the scheduling

The timetabling was carried out under the minimum number and area of classroom and following conditions.

The hard constraints;

Simultaneously conducted subjects shouldn't be separated.

Some subjects must be conducted at the same period.

Day and period for special subjects can't be changed.

A same teaching stuff cannot have more than one class at the same period.

The soft constraint;

Required subjects should be well balanced.

3 Minimum number and area of classrooms

At first, the minimum number of classrooms and their area were obtained as follows. The subjects in all departments from Monday through Friday are listed in a line starting from the subject which has the largest number of students and they are totaled by the top twenty subjects because there are four sessions a day for five days from Monday through Friday. The number of students for the top subject (the subject with the largest number of students) among this twenty is the number to be accommodated in the classroom of the group. This method determines the minimum number and area of classrooms required. The minimum number and area of classrooms were obtained by this method as shown in Table 1. In this case, it is very hard problem in order to obtain the optimum condition in which the classrooms do not conflict. Fig.8 is the one of the examples of the best result for the data in Table 1. The classrooms in Table 1 are very tight for the scheduling and it is not practical to make a various size of classroom. Therefore the classrooms in Table 2 were mainly used in this study.

Table1 Minimum number and area of classrooms

Accommodation	200	187	156	147	136	110	⋯	44	36	32	28	20
Number	1	1	1	1	1	1	⋯	1	1	1	1	4

Table 2 Minimum number and area of classrooms

Accommodation	200	187	156	147	136	110	106	86	70	52	36	20
Number	1	1	1	1	1	1	3	5	5	2	3	5

4 Objective functions and constraints

Class schedules are created under the condition of the minimum number and area of classrooms. In this case, there are a number of restrictions for this condition, and it was attempted to create the schedule under the following objective functions 'obj' and constraints for

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the classrooms in Table2.

Obj: $$\min \sum_{i=1}^{20} \left| \sum_{j=1}^{12} (x_{ij} - \sum_{k=1}^{27} y_{ijk}) \right| \quad (1)$$

i : i_{th} session from Monday first session. The maximum of i is 20(four sessions a day times five days a week). j : j_{th} size of the classroom from the largest classroom. The maximum of j is 12 (see Table 2). k : k_{th} class at each session that has 27 parallel classes. $x_{ij} \in \{1,1,\cdot\cdot 3,5\} =$ maximum number of j at i (see Table2).

$y_{ijk} \in \{0,1\}$: $y_{ijk} = 1$ if j at i and k is used. The optimum value of 'obj' is zero.

Though the main objective function is 'obj', the next function 'Averr' is also considered.

Averr: $$\min \sum_{i=1}^{20} \left| \sum_{l=1}^{6} (u_{il} - \sum_{m=1}^{4} v_{ilm}) \right| \quad (2)$$

$l : l_{th}$ department. The maximum of l is 12. $m : m_{th}$ grade of the six undergraduate school departments. The maximum of m is 4.

u_{il} : averaged value at i that is obtained by dividing the summed value by 20. The summed value is obtained by adding two for the required subject, one for the special elective subject and zero for the elective subject of all the subjects in l at i. v_{ilm} : value of subject that is two for the required subject and one for the special elective subject of m_{th} grade at l and i. Eq.2 means that the required subjects in the same department should be well balanced at the same session. Though 'minimize Averr' is not absolutely necessary, it decreases the load of the students. Therefore this can be said to be the soft constraint.

Other constraints;

1. Some subjects must be conducted at the same period.
2. Day and period for special subjects are not allowed to be changed.

5 Algorithm

5.1 Virus evolutionary theory

Imanishi's evolutionary theory posits that the evolution of species occurs drastically in a short period (horizontal evolution) after keeping its characteristics stable for a relatively long period. It is also presumed that the mechanism of Imanishi's evolutionary theory can be explained by the virus evolutionary theory [6].

5.2 GAV

By replacing the solving problem to an individual that consists of genes, the genes are recombined by the virus attack. The virus is composed of two genes, the top gene and the tail gene. Although there is only a single chromosome (individual), a population of viruses is generated in this algorithm. These viruses are mutated after the attack on the chromosome. If one of the viruses attacks the individual, the genes of the chromosome are attacked. The virus attacks the gene of the individual that is same to the top gene. In addition, the three-point recombination was also done in this study.

In this case, the infection (recombination) is admitted when the evaluation value goes up, but it falls into local minima immediately by this method. In order to escape from these local minima, an infection that makes the evaluation value worse in a small rate (rate of allowance AR) under a low probability (rate of permission PR) is recognized as well. In this case, PR and AR are made smaller as the evaluation value goes up in order to escape local minima.

After the infection, the genes of the virus are mutated. The mutation of viruses is very important for the improvement of the individual. By these performing these procedures, virus attack effectively improves the individual.

5.3 GAV for the timetabling

The general method of GAV that has been carried out in this laboratory[1][2] is descried in **5.2**. This GAV was applied for the class scheduling as follows. Fig.1 shows the Viruses and the chromosome (individual). Fig.1shows the chromosome for the classrooms of the undergraduate student. This is because of the simplicity of the explanation. Namely it consists of the classrooms from the first class of the first grade of mathematics to the last class of the fourth grade of applied chemistry. This row of the classrooms is called as a chromosome and each classroom is called as a gene in this study. The chromosome in Fig.1 is for the undergraduate course, therefore it becomes from 480 sessions. Actually there are sessions for the graduate course students in addition. Therefore the row consisted of 640 sessions was used for this scheduling. The viruses consisted of two genes exchange only the sessions of same grade of same department. In this case the genes of the viruses were changed randomly for the simplicity of the programming. The genes consisted of more than single gene at the same position means the subjects that can not be separated.

PR and AR are made smaller as the evaluation value goes up in order to escape the local minima. In this case, the value of PR is very small and AR can be taken comparatively large value. Therefore it is possible to seek the solution at comparatively wide search space even if the evaluation value becomes high.

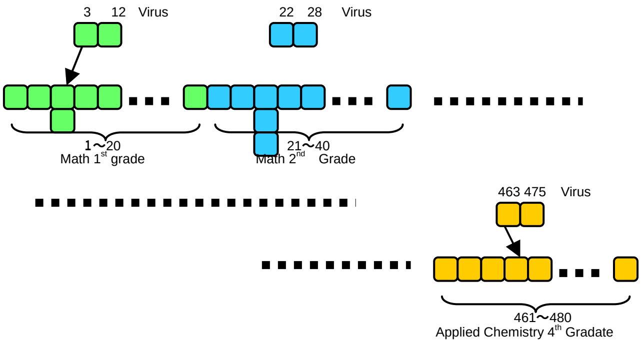

Fig.1 The chromosome and viruses

objf: value 'obj' of the initial state,
err1: value of 'Averr' at the previous state of rearrangement, and 'Averr' is the summed value of the absolute value of the difference from the average value of the number of the required subjects at the same period,
err2: value of 'Averr' after rearrangement,
lr: random numbers between 0 and 1,
c1,c2,c3,c4,c5 : parameters,
c2*obj1/objf: allowance rate AR1,
c5*obj1/objf: allowance rate AR2,
(c3+c3*obj1/objf): permission rate PR.

5.4 Program

```
Begin
    Generate the individual;
      Generate the population of the viruses;
        Repeat until the satisfactory solution is reached;
          Attack the individual by virus;   /*swap between two subjects*/
            Evaluate the objective function;
             If err1 >err2 and (c1+c2*obj1/objf)* obj1 > obj2) then begin
             Infect the virus;
             End;
      Attack the individual by virus;   /*swap between two subjects*/
      Evaluate the objective function;
               if obj>obj2 then begin
      Infect the virus;
               End;
      else if lr<c3+c3*obj1/objf   then begin
          if (c4+c5*obj1/objf)* obj1> obj2) then begin
          Infect virus;  /* admittance of the swap between two subjects*/
           End;
      End;
        Attack the individual by the virus;  /*swap among three subjects*/
        Evaluate the objective function;
              if obj1>obj2 then begin
                 Infect the virus; /*admittance of the swap among three subjects*/
            End
        End of repeat;
  End.
```

Where
obj1: value of 'obj' at the previous state of rearrangement, and 'obj' is the value of objective function that is the twice number of conflict usage of the classrooms,
obj2: value of 'obj' after rearrangement,

6 Experiments

The Experiments were done as follows;

1. The trials of the program were done by 10000 iterations.
2. The data was obtained by ten trials
3. The best parameters were sought for each parameter.
4. The data was obtained for various values of the parameters c2, c3 and c5 while c1 and c4 were kept constant value 1.

Fig.2, Fig.3 and Fig.4 are the results for Table 2 and Fig.8 is for Table 1.

The initial state of the class schedule has considerable uselessness showing 240 as the value of 'obj' and the state of the required subjects is uneven as shown in Fig.2.

Fig.3 is the case that AR and PR are not admitted. Namely c2, c3 and c5 are zero in their value. In this case, it falls into local minima immediately though the improvement is done quickly near the start. The value of 'obj' is 28 in this case. It is impossible to escape from the local minima after once falling into the local minima.

Fig.4 is the case where the best result was obtained. The values of the parameters for c2, c3 and c5 were 0.02, 0.0003 and 0.06 in same sequence. The optimum combination was obtained in this case. 'obj' was greatly improved as compared with the value 240 at the initial state. It approached even as for the number of students of each time zone of each department though it was considerably uneven at the initial stage. The required subjects were balanced as well. Moreover, the total number of students was almost leveled at each period on each day of the week and it means that the classrooms are used efficiently.

Next, the experimental results obtained by changing the value of parameters c2, c3 and c5 are shown in Fig.5,6 and 7.

Fig.5 is the result by changing the value of c2 while other parameters are fixed as c1=1 c3=0.0003 c4=1 c5=0.06.

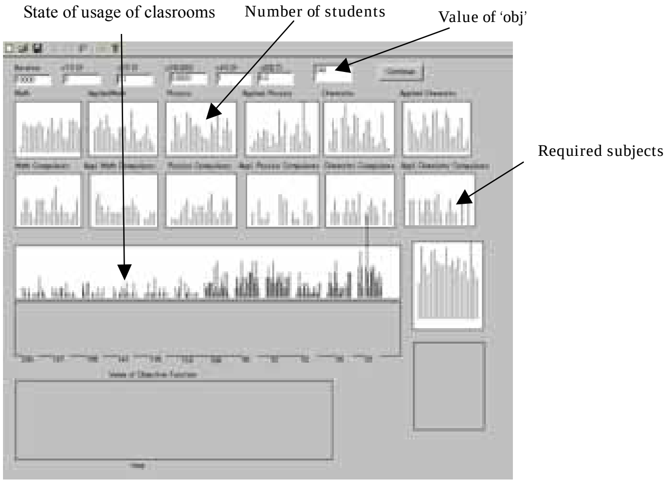

Fig.2 The initial state

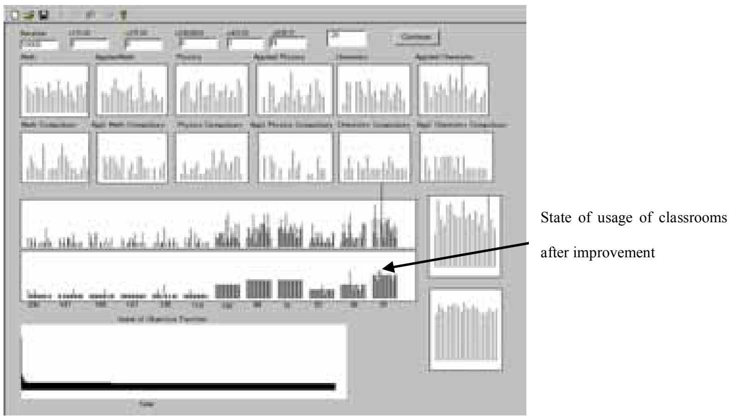

Fig.3 Case that AR and PR are not admitted

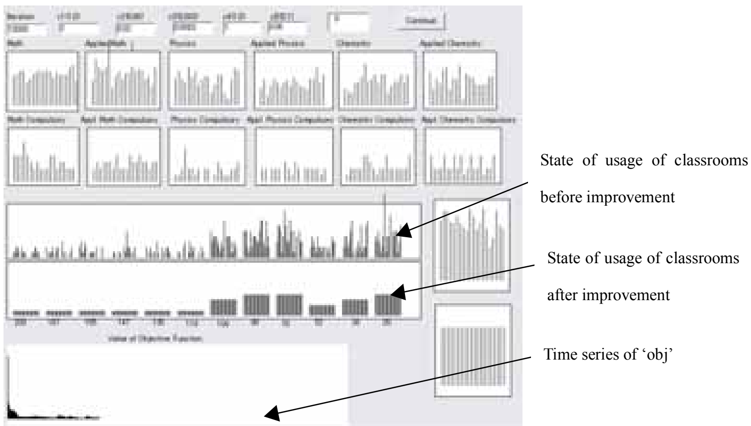

Fig.4 Case that the optimum condition was obtained

The line chart indicates the number of times that the optimum solution was obtained. The bar chart shows the average of the minimum values among the ten trials. As shown in Fig.5, when c2 became more than around 0.10, the evaluation values became worse rapidly. Although significant difference among the evaluation values for c2 less than 0.10 can not be recognized, the best result was obtained in using c2 of 0.02.

Fig.6 is similar one to that of Fig.5. In this case, the value of c3 was changed while other parameters were fixed as c1=1 c2=0.002 c4=1 c5=0.06. The best result was obtained at the value of 0.0003 for c2.

Fig.7 shows the similar result to Fig.5 and 6. In this case, the data was obtained by changing the value of c5 while other parameters were fixed as c1=1 c2=0.02 c3=0.0003 c4=1. In this case, significant difference can not been seen between the value of 0.0000001 and 0.02. But it can be said that the solution is likely to fall into local minima. In case of c5=0.06, the best result was obtained.

Fig.8 is the case where the data in Table 1 was used. In this case, the combinatorial problem becomes far difficult in comparison with the case of Table 2. Fig.8 is the case that the best result was obtained. The classroom of 36 accommodations conflicts at one point and is not used by one point as shown in Fig.8. Namely the value of 'obj' is two. The results for Table1 have been obtained to some extent. Although it is necessary to investigate more precisely, the result of Fig.8 shows that the data of Table1 is considered to be the minimum number and area of classrooms.

7 Conclusions

The minimum number and area of the classrooms were obtained and the timetabling for the classrooms was tried. As a result, the optimum condition for the timetabling was possible.

It was also possible to make the required subjects more even and it means that the load of students was

lessened.
In case of c1=1 c2=0.0 c3=0.0 c4=1 c5=0.0, the solution falls into the local minima immediately and it is very difficult to obtain the optimum value.
The escapement from the local minima was attempted by changing the value of the parameters. It is effective in order to escape from the local minima that the allowance rate AR and the probability rate PR are decreased as the value of the objective function approaches to the optimum value. The parameters c1=1 c2=0.02 c3=0.0003 c4=1 c5=0.06 were the best values.
In this report, the combinatorial problem was solved and the optimal parameters were sought. The main purpose of this study is to obtain the data of the minimum number and area of classrooms for the construction of the new building. For this aim, this method is useful.

8 References

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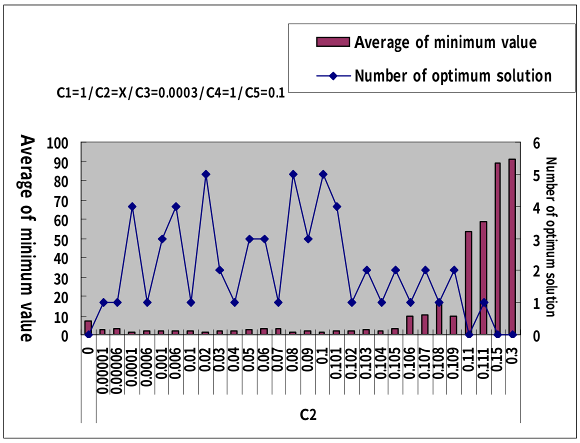

Fig.5 The results obtained by changing c2

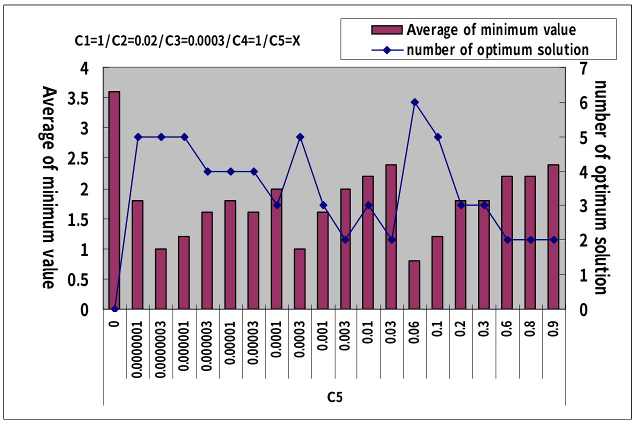

Fig.7 The results obtained by changing c5

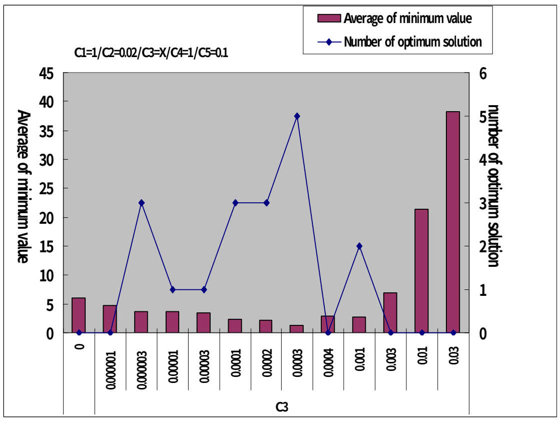

Fig.6 The results obtained by changing c3

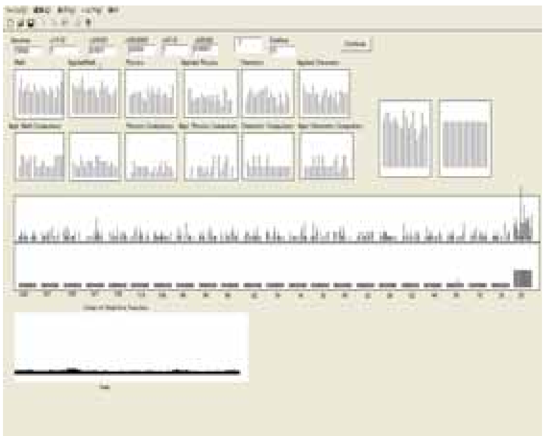

Fig.8 The best result for the data of Table1