Comparing Selection Method in Course Scheduling Using Genetic Algorithm

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Abstract—Selection technique is an important operator in genetic algorithm (GA). Defining the best selection technique is critical in order to get the optimum solution for certain problem. The purpose of this study was to compare 3 selection techniques in high school scheduling problem using distributed GA (DGA). The selection techniques implemented in this study were roulette wheel, tournament and truncation selection. The migration probabilities used in DGA was 0.5. The results showed that the best selection method in avoiding early convergence is the tournament method.

Keywords—DGA; roulette wheel; tournament; truncation; genetic algorithm, selection technique

I. INTRODUCTION

The process of build a schedule between rooms, subjects, students and teachers to avoid the constraints violations is called timetable problem (TTP) [1]. The constraints can be hard or soft. To build a schedule for senior high school, some resources need to be arranged, so that the hard constraints violation can be avoided. The difficulty in preparing a schedule is limited resources and the resulting schedule cannot violate existing constraints.

There are many algorithms in solving TTP such as local search [2,3], simulated annealing[4,5], cultural algorithm [6], and genetic algorithm(GA) [1,7-16]. An improved version of GA was using distributed population in GA that called distributed GA (DGA). Study [17-19] used DGA to solve combinatory problems. In DGA, there is an important operator, the migration rate. This operator control how individual exchange among groups. This rate can be constant or adaptive as found in study [20]. The adaptive parameter generally based on the fitness on certain generation, so the user will not be difficult to determine the parameter. Earlier study [21] using DGA to solve senior high school scheduling. The study showed that probability of migration (pmig≥0.3) can reach the maximal generation of GA.

The DGA operators include selection technique, crossover rate, mutation rate and migration rate. Selection plays an important role in DGA. The appropriate selection technique will lead to the optimum solution. There were many studies that comparing selection technique. Zhong et al. [22] compared tournament and roulette wheel in simple GA (SGA). The numerical experiments showed that roulette wheel selection converges much slower than tournament selection in SGA. Other study done by Razali et al. [23] and Pandey et al. [24] compared tournament, roulette wheel and rank selection in travelling salesman problem (TSP). The first study [23] found that rank-based and roulette wheel are suitable for large size problem while the tournament selection can be used for smaller size problem. The second study [24] showed that tournament selection was the worst technique in terms of distance resulted. The better technique was roulette wheel, while rank-based selection was the best technique. Comparing selection technique also done by [25]. In that study three selection techniques: stochastic universal sampling, tournament selection and roulette wheel were compared. The study found that the roulette wheel technique produces more stable fitness value than the stochastic universal sampling and tournament selection. Chudasama and Panchal [26] compared roulette wheel, tournament selection and elitism selection method. The study conclude that elitism method was the best method. While Gangwar et al. [27] compared truncation selection, proportionate selection, roulette wheel selection, rank selection, steady state selection and tournament selection. The study showed that tournament selection was the best technique that gives the best chromosomes to fight in the tournament. Sohal et al [28] compared Elitism selection, rank selection, roulette wheel selection, tournament selection, Boltzmann selection and steady state selection. The result showed that the elitism in GA give the better speed to converge and result the optimal chromosome (solution) than the GA without elitism. Shukla et al [29] did a comparative review of ranking selection, tournament selection and roulette wheel selection. The study conclude that tournament selection give the better result in time complexity and convergence rate.

This study aims to explore the best selection technique in DGA for senior high school scheduling in order to reach the most optimal fitness and generation. Here three kinds of selection techniques: the tournament, roulette wheel and truncation selection were compared.
II. METHODOLOGY

A. Distributed Genetic Algorithm

One of heuristic technique for searching to solve the combinatorial problem is genetic algorithm (GA) [30]. Genetic algorithms is widely use in several studies. The first step in GA is generate a set of random solution called population. A solution will represent as an individual called chromosome. The initial population will evolve during the iteration. Each iteration will produce one new generation. Each new generation is produced by selection, crossover and mutation. Each individual will be evaluated by a fitness function that indicates the resilience degree of the individual in adapting to the problem. After several iterations, the GA will converge on the best individual, which is expected to be the optimal solution for certain problem.

The DGA is a modification of a simple GA (SGA) to avoid the premature convergence. The different between SGA and DGA is DGA generates several population groups at once. For each iteration, the GA process will be conducted in each group. The migration of individual/chromosome between groups is conducted in the end of iteration process based on the migration rate. This migration is expected to keep the variation of the member in population, so that the local optimum can be avoided. The DGA flowchart in this study is shown in Figure 1.

B. The Representation of Chromosome

The solution or chromosome was represent using data structure as below:

```
TClass
  nameOfClass : String,
  shift : byte
end of TClass;
Class = array[1..j] of TClass;

TSection
  name : String,
  timeslot : byte
end of TSection;
Section = array[1..k] of TSection;

TChromosome
  course
  teacher
end of TChromosome
Individual = array[1..j,1..k] of TChromosome
```

Individual = array[1..j,1..k] of TChromosome

A chromosome will be composed of course and teachers. Individuals are represented in a two-dimensional array, where the first index represents the class index, while the second index represents the section index. For example, when index 1,1 shows the geography lesson and instructor Andi, then using class 1 will get a Geography taught by Andi in a session with index 1 (in the session there are course and hours).

C. Fitness Function

There are two kind of constraint in this study, the soft and the hard constraints. The hard constraints are cannot be violated in the solution provided by GA, while the soft constraints can be violated, but the violation will decrease the fitness value of the solution. Any violation of the soft constraint will be subject to penalty. The more violations will result the bigger penalty for the solution. The objective of this study was to minimize the total penalty. The fitness function of this case is as follow:

fitness = 1/(1+total_penalty)  \hspace{1cm} (1)

where total_penalty is the sum of all penalty caused by the soft constraint violation.

D. Selection

The selection aims to select a couple of parent to produce new offsprings. The selection method used in this study was roulette wheel, tournament and truncation method. The parent selection in roulette wheel is based on the proportion of the fitness. The probability of chromosome to be selected as a parent is affected by the fitness. The greater fitness will give the greater opportunity to be selected. Based on [31], the pseudo code of the roulette wheel method is as follow:

```
program RouletteWheelSelection 
  inputs :
  outputs :
  procedure
    Calculate the sum S=\sum_{a=1}^{n}f(a);
    For each chromosome i=1 to n do{
      
    }
end program
```

Fig. 1. The modified DGA flowchart[21]
o Generate a random number $r \in [0, S]$;
o $\text{Sum} = 0; b=0$;
o do{
  $\text{Sum} \leftarrow \text{Sum} + f(b)$;
  $b \leftarrow b+1$;
}o while ($\text{Sum} < r$ and $b < n$)
  select the chromosome $b$;
}

The tournament selection will choose $k$ number of individual and then rank all $k$ individual to get the best $2$ individual as a couple of parent. The pseudo code of tournament selection is as follows:

**TS_pseudo-code**

```plaintext
{  
  • Select $k$ random individual from population and place in an array S  
  • Sort the array S based on the fitness descending  
  • Pick top 2 individual
}
```

The truncation selection [32] is the simplest technique. The technique orders the chromosome of each population based on the fitness. Then, only a certain portion $p$ of the fittest individuals are selected and reproduced $1$ p times. It is less used in practice than other techniques, except for very large population. The pseudo-code of the technique is as follows [31]:

**TRS_pseudo_code**

```plaintext
{  
  • Order the $n$ chromosomes of $P(i)$ based on their fitness;  
  • Set the percentage $pt$ of chromosomes to select (e.g. $10\% \leq pt \leq 50\%$)  
  • $c_{\text{number}} = n \times p$  
  • Select the first $c_{\text{number}}$ chromosomes;
}
```

**E. Crossover**

Crossover is conducted to produce a new offspring. The one-point crossover is used in this study. Because this technique simpler than others, so the time complexity can be reduced. The rate of crossover is defined by the probability of crossover (pc). Higher pc will produced more offsprings.

**F. Mutation**

Mutation happened after crossover. It will change the genes in chromosome. The probability of mutation happened is based on the mutation rate/probability of mutation (pm). Generally, the value of pm is small, because based on fact the mutation probability is low. This process aims to prevent the premature convergence. In this study, the genes will be change if the mutation is happened, that means the teacher will be change by other teacher.

**G. Elitism**

Elitism is done in the end of iteration to eliminate the chromosomes that have the worst fitness. All of the offspring resulted by the crossover will be compared to all chromosomes in a population. If the fitness of the offspring is lower than all of the population members, so the offspring will not be a new member of population. On the other hand, if the fitness of the offspring is greater than one or more of the population member, the worst chromosome in a population will be eliminated. The elitism will keep the fittest chromosome over generation.

**H. Chromosome Migration Between Groups**

The DGA used in this study based on earlier study[21]. The DGA works with several number of population groups. One groups is consist of some chromosome. There will be a migration between one group to other group, so the chromosome in each group will be varied and the premature convergence is expected to be prevented. The migration will happened based on the migration rate/migration probability (pmig).

### III. RESULT

This study used the scheduling case in SMA Surya Wisata, Jalan Wagimin, Kediri, Tabanan. The hard constraints are shown in Table I, while the list of soft constraint are shown in Table II.

**TABLE I. THE LIST OF HARD CONSTRAINTS**

| No | Hard Constraint |
|----|-----------------|
| 1  | The teacher only teach the course according to their field |
| 2  | One teacher cannot be in two or more class on the same section |
| 3  | The first section on Monday cannot be assign in any course, because a national ceremony is held every Monday morning |
| 4  | One class cannot take one course in 4 hours or more in the same day |

**TABLE II. THE LIST OF SOFT CONSTRAINTS**

| No  | Soft Constraint                                                                 | Penalty |
|-----|---------------------------------------------------------------------------------|---------|
| 1   | Total teacher’ section in a week exceed 50 hours or more                        | 12      |
| 2   | Total teacher’ section in a week exceed 45 hours or more                        | 11      |
| 3   | Total teacher’ section in a week exceed 40 hours or more                        | 10      |
| 4   | Total teacher’ section in a week exceed 35 hours or more                        | 9       |
| 5   | Total teacher’ section in a week exceed 30 hours or more                        | 8       |
| 6   | Distribution of uneven teaching hours for teachers in one area                  | 8       |
| 7   | Total teacher’ section in a week exceed 25 hours or more                        | 7       |
| 8   | Total teacher’ section in a week exceed 20 hours or more                        | 6       |
| 9   | A class get 3 hours of the same lesson on the same day                          | 6       |
| 10  | The morning lessons are completed over the 9 sections                          | 5       |
| 11  | The morning lessons are completed over the 8 sections                          | 3       |
| 12  | The afternoon section completed over 9                                          | 5       |
| 13  | The afternoon section completed over 8                                          | 3       |
| 14  | Lesson hours with 2 section/week load broken down on different days             | 2       |
| 15  | There are interlude of lessons in a class                                       | 1       |

The hard constraint is the constraint that cannot be violated by the chromosome resulted in GA, on the other hand, the soft constraint violation will affect the fitness. The more soft
constraints are violated, the smaller fitness resulted by the solution.

The classes (group of students) were managed in this study were: 9 classes of first year students, 9 classes of second year students and 9 classes of third year students. Some of classes were held in the morning session while the others were afternoon session. Each session will divided into time sections. Each class has their fix classroom. The DGA will managed 61 teachers for certain class, time section and course in order to generate a good schedule. The genetic parameters were shown in Table III.

| TABLE III. | THE PARAMETERS IN THIS STUDY |
|------------|-----------------------------|
| The population group number (group) | 4 |
| Chromosome number in each group | 50 |
| Maximal generation number | 1000 |
| Probability of crossover (pc) | 0.8 |
| Probability of mutation (pm) | 0.1 |
| Probability of migration (pmig) | 0.5 |
| k for tournament selection | 10 |
| F for truncate selection | 40% |

The number of population generated in each group was 50 chromosomes. Then crossover is conducted based on the pc, the number of selected parent in one crossover is two chromosome, and it will result two new offspring. The mutation rate pm is set to be low. After the elitism procedure is done, the migration between groups is conducted based on the pmig. All of the process will be repeatedly conducted until the maximal generation is reach or all of the group reach their convergence state. Convergence state will be happen when the best fitness in the group is the same for 100 generation. The experiment was conducted 30 times for each selection technique. The results of experiments was shown in Table IV.

| TABLE IV. | THE EXPERIMENTAL RESULT |
|-----------|-------------------------|
| Selection method | Max gen | Average Fitness | Best Fitness |
| Roulette wheel | 496 | 0.031 | 0.045 |
| Tournament | 687 | 0.043 | 0.051 |
| Truncation | 153 | 0.024 | 0.025 |

In Table IV, we can see that the comparison between each selection method. From the table we can conclude that the tournament selection give the longest run of generation, while the fastest method to converge was truncation. Because the truncation method converge so fast, this imply to the low fitness. The largest average and best fitness was resulted by tournament selection.

IV. CONCLUSION

This study used distributed genetic algorithm (DGA) and 3 selection methods to solve the time table problem in senior high school. This study managed the teacher and course into different classes and sections. Based on the experiment result, the best selection method was tournament method. This method gave the best average fitness compared to other and prevent the algorithm from premature convergence. The fastest convergence was reached by truncation selection. For further work, we suggest to investigate the various crossover technique for time table that give the better fitness.

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