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Team-Teaching-Based Course Scheduling Using Genetic Algorithm

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Abstract

Scheduling problems occur in various fields, e.g., education, health institutions, transportation, sports, etc. Main scheduling problems in education is course scheduling which creates schedules for students and lecturers. In this study, course scheduling allocates the lecturers in the form of team teaching and courses into the class and a certain time to even out the workload of lecturers per day and a group of students per day in one week without breaking the constraint. The method used in this research is a genetic algorithm where Universitas Bhayangkara Jakarta Raya as the case study. The genetic algorithm process is done by getting several candidate solutions that undergo a process of selection, mutation, and crossing over to produce chromosomes with the best fitness values. The objective function in this research is minimizing the average variance of the workload of lecturers and students per day in one week. The parameters used in genetic algorithm are determined based on the Design of Experiments mechanism (DOE). The optimal parameter values used to run the program are as: population size = 50, with probability of crossing over = 0.4 and probability of mutation = 0.008. The results of scheduling with genetic algorithms show that the value of the workload variance lecturers and students by considering team teaching is better than actual scheduling. The application of the genetic algorithm method results in a decrease in the standard value deviation of the workload of lecturers and a group of students in one week is 0.114 (3.68%) and 3.11 (55.7%). In addition, course scheduling uses a genetic algorithm with consider team teaching better than genetic algorithm without considering team teaching because there is no class schedule that clashes in real conditions.

***Keywords**: genetic algorithm, scheduling system, subject of study, team-teaching*

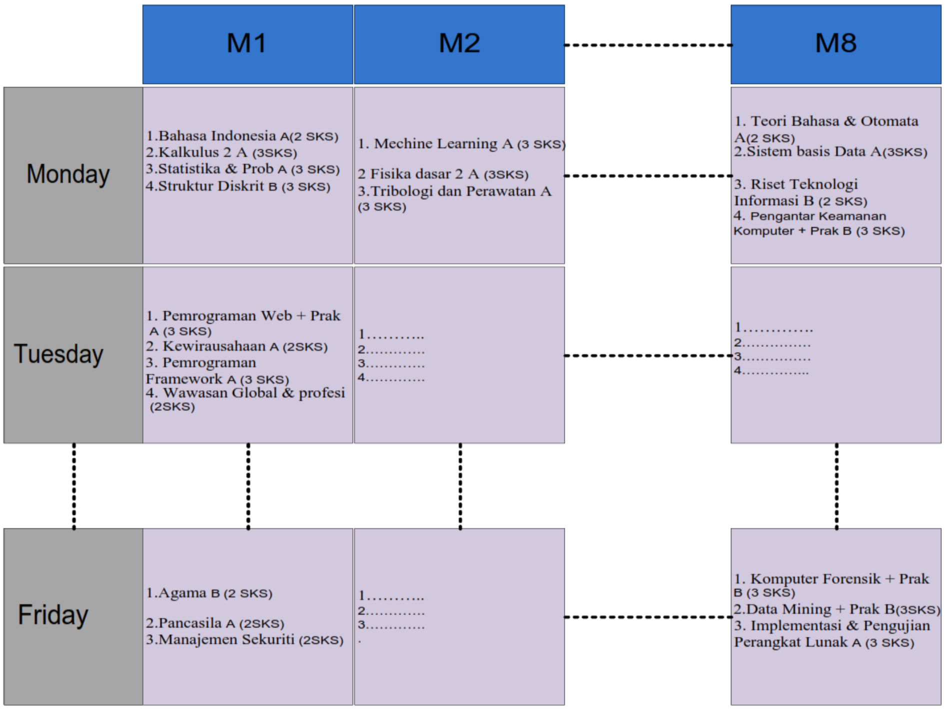
1. Introduction

Scheduling courses is a very complex problem. The essence of course scheduling is how to schedule the course based on classes, subjects, lecturers, space and time with a number of certain limitations and conditions. Class scheduling included in the type of schedulling. Schedulling problems can be classified as NP-

Hard Problem (nondeterministic polynomial time). The NP-Hard Problem is a problem that if all alternative combinations are tried to be tested, then the time needed to find the right solution feasible of the problem will increase sharply (Birbas, 2007). Therefore, the solution optimization will be difficult to solve using conventional methods (Kanoh & Sakamoto, 2008).

Students and lecturers are the main components in the teaching system that must be scheduled (Chaudhuri & De, 2010). Scheduling that pays attention to students and teaching staff, such as student learning workload and teaching staff preferences will result in good scheduling. Good scheduling will improve the quality of teaching and learning. Scheduling problems Lectures at educational institutions have many variations according to the policies of educational institutions where the class schedule is used. Scheduling courses at an educational institution is used as a as a case study where the preparation uses a manual method that does not use a algorithm often become the NP-Hard problems. The manual method has limitations for creating scheduling that involves a lot of components in educational institutions. Scheduling using the manual method takes a long time to get a schedule that is in line with expectations. Therefore, this research aims to develop a model for scheduling courses in educational institutions including existing limitations and team-teaching implementation.

Many research on scheduling has been studied, e.g., exam and course scheduling problem in a university (Qu et al., 2006). Kanoh & Sakamoto (2008) completed the schedulling course by using a combination of local search and algorithms genetics to find the optimal solution to meet the soft constraints. Good scheduling is obtained of several individuals during the running process in the model. The method used in solving it is knowledge based (KB). The knowledge based method will produce a partial solution that is entered in the Genetic Algorithm (GA) model in each generation. The results of this study indicate that the model genetic algorithm with the addition of prior period/knowledge based scheduling information is better than the genetic algorithm model without the addition of prior period/knowledge based scheduling information. Gooi, et.al (2010) optimize the workloading staff by involving 250 academic staff and 400 college student. The staff in this study indicate the teaching staff who in the model are scheduled for assignments teaching. There are five types of classes in one semester that must be met in carrying out assignments teaching so that weekly schedulling becomes feasible. The five classes are lecture, tutorial, project, design, and laboratories, whereas the constraints used in the model, namely Hard, medium, and soft constraints. Which method used to get the optimal value of this problem is Simulated Annealing (SA). M. Eley (2006) perform scheduling optimization with the aim of evening out the student learning load and distribute the test points evenly. The Max Min Ant Systems (MMAS) method is used in this study to find the optimal solution.



Source: Research Result

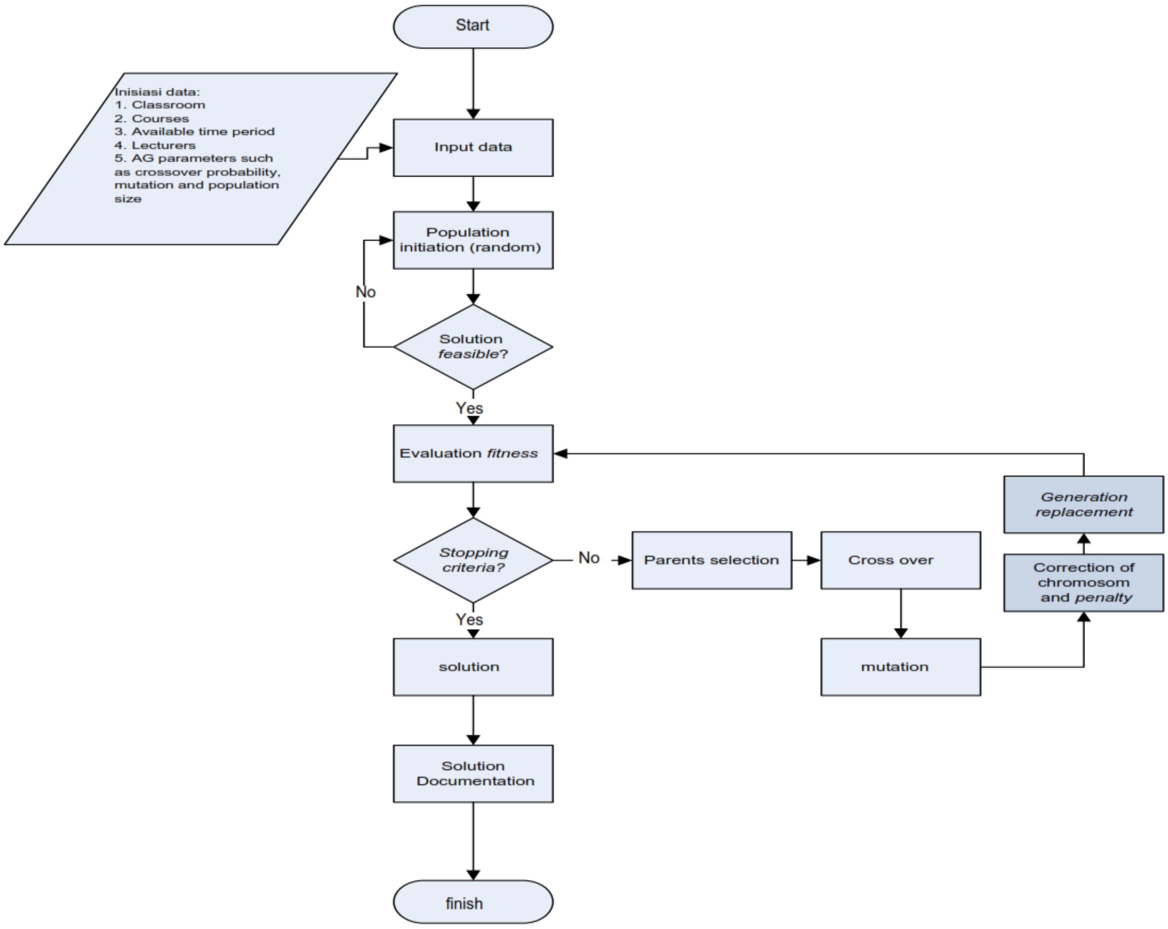
Figure 1. Illustration of the Use of Class for Courses

The results of this method are compared with several methods of Ant Colony and Ant Colony with Hill Climbing. Comparisons were made by testing on 13 different university data sets, with the results of comparisons varying across all data. Then Birbas (2007 used the integer programming method for scheduling Shift Assignment for teaching staff, which obtained a feasible teaching schedule that did not experience conflicts, and there was a schedule fit between the teaching staff and students. In addition, Darmawan & Hasibuan (2014) conducted research on course scheduling based on the distribution of the workload of lecturers and students evenly without considering team teaching. The method used to find the optimal solution of the course scheduling problem is the genetic algorithm method. The result is in the form of teaching scheduling and the distribution of the workload of teaching staff and students.

This research was conducted to obtain a schedule of courses in the Informatics field of study, Faculty of Computer Science, Universitas Bhayangkara Jakarta Raya (UBJ). The objective of this study including: i) the number of conflicting courses can be reduced, ii) the number of available lecturers can teach according to the maximum credit load, iii) the student lecture load is more evenly distributed, and iv) the use of classrooms is more optimal. The optimization method used in this study is a genetic algorithm (GA). Genetic Algorithm is one of the algorithms that can be used to solve problems on a large scale and has a high level of complexity so that it is suitable for solving the problem of scheduling courses at universities which are known to be complicated and have many variable constraints in making class schedules. The expected result of this research is an optimal course schedule.

2. Research Method

In general, the research flow chart can be seen in Figure 2.



Source: Research Result

Figure 2. Flowchart of Course Scheduling Using Genetic Algorithm

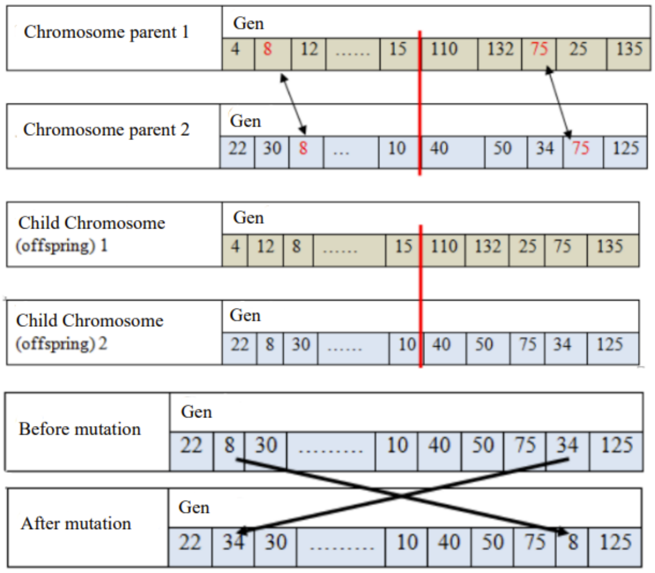
The data used to compile the class schedule is obtained from a database regarding administration of lectures in an educational institution. The data include list data room, teaching staff data for certain courses, time period data for certain subject units, data courses in a certain period of time, data on the year of class, majors, types of courses and credits for each subject studying. An illustration of the use of space for courses on a daily basis can be seen in Figure 1. The software used in this research is Matlab R2016a inside the Windows 10 operating system, for writing and building algorithm models. The method is Genetic Algorithm where this method is a heuristic method or approach that mimic the processes of natural selection and evolution from Charles Darwin.

The model of the chromosomes in the genetic algorithm is adjusted to the shape of the course schedule at the institution education, where the chromosome consists of several genes. Genes are formed is a representation of the schedule courses for certain lecturers on certain days in certain time slots, as well as intended for students of certain study programs and certain semesters. Representation of simple chromosomes in the case of akademic scheduling as shown in Figure 3. The crossover and mutation method used are one-point crossover and swap mutation, respectively, as can be seen in Figure 4.

	Monday														
	M1					M2			......				M8		
Time / POP	1	2	3	4	5	1	2	3					1	2	3
1	42	23	21	8											
2	1	14	30	5											
......															
25	45	130	90	4											

Source: Darmawan & Hasibuan (2014)

Figure 3. Chromosome Representation Illustration



Source: Darmawan & Hasibuan (2014)

Figure 4. One Point Order Crossover Process and Mutation Process using the Swap Method

Parent selection is done by the roulette wheel method. In this selection method, parents are selected based on the fitness value, the better the fitness value, the more likely it is to be selected. Process parent selection begins by doing a linear fitness ranking (LFR) with the aim of increasing variation so as not to occur local optimum and further clarify the position between the chromosomes with their fitness. Linear Fitness Ranking is done after fitness is sorted from the largest to the smallest LFR formula expressed in the following equation (Russell, 2018):

$$LFR_k = F_{max} - (F_{max} - F_{min}) \times \left(\frac{n_k - 1}{n_p - 1}\right) \tag{1}$$

where

LFR_k : Linear fitness rangking

MaxF : Fitness maximum in one population

MinF : Fitness minimum in one population

k : Chromosom number

n_p : Size of the number chromosomes in one population

n_k : Index of number from 1 to n_p

The Design of Experiment (DOE) was carried out to find the genetic algorithm parameters, i.e., number of populations, crossover rate and mutation rate where the results are as follows, respectively, 50; 0.4; and 0.008. The solution search process is carried out up to 1000 iterations, and generally it looks convergent.

3. Results and Analysis

Mathematical models are represented to describe course scheduling problems at institutions education. The mathematical model is formulated as follows:

a. Course set (*j*)

   j = index of courses contained in the academic period offered, j∈{1,2,3,…J}

   J = the total number of courses

b. Starting time (*i*)

   i = index of the period or time of the course being implemented, i∈{1,2,3,…Q}

   Q = the total period or time of the courses carried out

c. Room (*r*)

   r = index of available classrooms, r∈{1,2,3,…rk}

   rk = the total number of usable classrooms

The objective function to be formulated by the model is (Kristiadi & Hartanto, 2019):

a. Minimize the distribution of the lecturer's workload per day in one week while considering the competence.

$$S_l = \frac{\sum_{h=1}^{H}\left(B_{hl} - \sum_{h=1}^{H}\frac{B_{hl}}{H}\right)^2}{H} \quad (2)$$

$$XD = \sum_{l=1}^{L}\frac{S_l}{L} \quad (3)$$

   Where *S* = Lecturer load variance, *B* = Lecturer credit load (sks), *XD* = average variance of lecturer load per day in one week, *l* = lecturer (*l*=1,2,3,….*L*), *L* = set or number of lecturers, and *h* = day (*h*=1,2,3…*H*).

b. Minimize the distribution of the workload of a group of students per day in one week

$$SM_l = \frac{\sum_{h=1}^{H}\left(M_{hl} - \sum_{h=1}^{H}\frac{M_{hl}}{H}\right)^2}{H} \quad (4)$$

$$XM = \sum_{l=1}^{L} \frac{SM_l}{L} \tag{5}$$

Where *SM* = Student load variance, M = Student credit load (sks), and *XM* = Average student load variance per day in each week.

The limitations of this model are (Buontempo, 2019):

a. Courses are scheduled once on a certain day, a certain time slot, and in a certain room. This is expressed through the equation 6.

$$\sum_{i=1}^{Q} \sum_{j=1}^{N} \sum_{r=1}^{rk} X_{ijrh} = 1 \,, \forall\, h \in H \tag{6}$$

where

X_{ijrh} = 1, if course j is scheduled on day *h*, room *k* and at starting time *i*

X_{ijrh} = 0, if course j is not scheduled on day *h*, room *k* and at starting time *i*

b. A lecturer cannot teach more than one subject at a certain time period at the same time. This is expressed through the equation 7.

$$\sum_{j \in li} \sum_{r=1}^{rk} \sum_{i=1}^{i+sks_j} X_{ijrh} \leq 1,\ \forall\, i \in \{1,2,3, \dots Q\}, \forall\, l \in \{1,2,3, \dots L\}, \forall\, h \in \{1,2,3, \dots H\} \tag{7}$$

where

J_l = a collection of courses taught by the l^{th} lecturers

SKS_j = number of credits in the j^{th} courses

c. A room cannot be used for more than one course at the same time. This is expressed through the equation 8.

$$\sum_{j=1}^{N} X_{ijrk} \leq 1 \,, \quad \forall\, i \in Q, \quad \forall\, r \in rk, \quad \forall\, h \in H \tag{8}$$

d. Each course must have a total time allocation according to the weight of the credits. This is expressed through the equation 9.

$$\sum_{i=1}^{Q} \sum_{r=1}^{rk} X_{ijrh} \leq Dj \,, \quad \forall\, h \in H \tag{9}$$

where, D_j is duration for courses *j*

e. Every lecture activity must stop before or at the end of the activity at the institution, therefore equation 10 is used to limit the time

$$\sum_{i=1}^{Q} X_{ijrh}\,(i + sks_j) \leq F, \forall\, j \in N, \qquad \forall\, h \in H, \qquad \forall\, r \in \{1,2,3, \dots rk\} \tag{10}$$

where F is time of completion of Institutional activities.

f. The maximum number of parallel courses for the same class year is P_{max}, in a certain period. The above limitations are expressed through the equation 11.

$$\sum_{p=1}^{G_s} \sum_{rp=1}^{R_p} \sum_{r=1}^{rk} \sum_{i=1}^{i+sks_j} Z_{spr_p rih} \leq P_{max} \;\; \forall\, i \in \{1,2,3, \dots Q\}, \qquad \forall\, s \in \{1,2,3, \dots S\}, \quad \forall\, h \in \{1,2,3, \dots H\} \tag{11}$$

Where,

s = semester

S = number of semesters

p = parallel courses in semester s

G_s = parallel courses in semester s

r_p = parallel course class p

R_p = number of classes for parallel courses p

Where,

$Zspr_prih$ = 1, if the courses are in the ***s*** semester, for the type of parallel courses ***p***

and class ***r*** are scheduled on day ***h***, room r and at starting time ***i***.

$Zspr_prih$ = 0, if the courses are in semester ***s***, for parallel courses type ***p*** and class ***r***

are not scheduled on day ***h***, room ***r*** and at starting time ***i***.

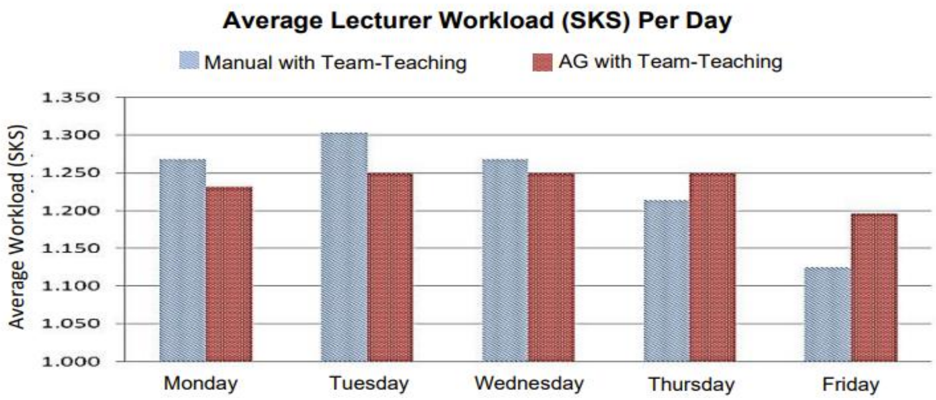
GA that implements the team teaching compares with manual scheduling based on the average standard deviation of the load of lecturers and students per day in one week is shown in Table 1.

Table 1. Scheduling Results Comparison

Method	**Mean of Standart Deviation**	
	Lecturer	**Students**
Manual method with team-teaching	1.604	4.12
GA with team-teaching	1.313	1.18

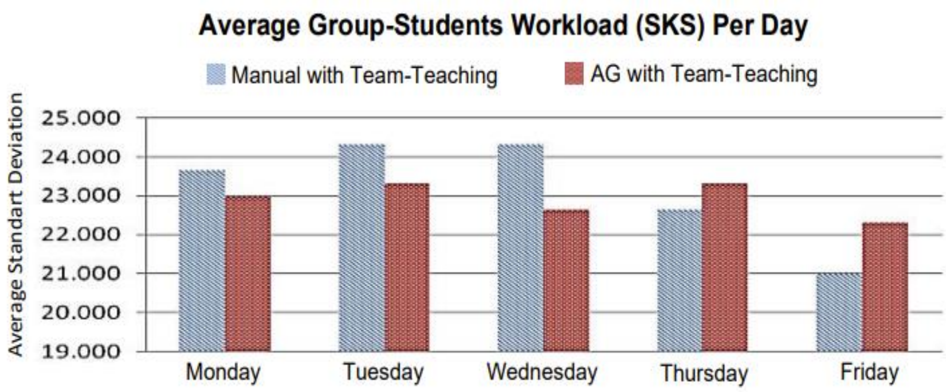
Source: Research Result

Based on Table 1, the scheduling of courses uses a genetic algorithm by paying attention to team teaching gives better results in terms of the distribution of the lecturer's workload and students, compared to manual scheduling. Scheduling using the GA method by paying attention to team teaching is able to reduce the average standard deviation of lecturer workloads per day (XD) as much as 0.114 or 3.68% and the average standard deviation of the workload of a group of students per day (XM) as much as 3.11 or 55.7%. The average workload of lecturers and students per day is shown in Figure 5 and Figure 6.



Source: Research Result

Figure 5. Graph of Average Lecturer Load (SKS) Per Day



Source: Research Result

Figure 6. Graph of Average Group-Students Workload (SKS) Per Day

The results of the genetic algorithm scheduling by considering team-teaching then compared with the results of the genetic algorithm scheduling without team-teaching that has been carried out in previous research (Laksono et al., 2016). Scheduling with team-teaching in mind will make the resulting schedule more realistic as shown in Table 2.

Table 2. Comparison of Course Clash Schedules in Real or Actual Conditions

Method	Clash schedule when faced with real conditions
AG with team teaching	No
AG without team teaching	7 Schedule clash

Source: Research Result

4. Conclusion

Based on the results of the scheduling model using the Genetic Algorithm using Matlab software, the proposed scheduling of courses in the Informatics study program of UBJ produces a new schedule that is feasible with the best fitness value. The resulting schedule is close to the desired ideal condition with a *hard constraint* penalty of 0 and a *soft constraint* penalty of 8. The scheduling program that has been made has not involved the limitations of the lecturer's teaching schedule and the lecturer's team teaching. However, it can still be improved by adding an input matrix of the relationship between time and lecturers, and a matrix of lecturers' areas of expertise (team teaching).

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Author Contributions

Rafika proposed the topic; Rakhmat for collecting of primary and secondary data; Rafika, Rakhmat and Khairunnisa conceived models and designed the experiments; Rafika conceived the optimisation algorithms; Rafika and Khairunnisa analysed the result.

Conflicts of Interest

The author declare no conflict of interest.

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