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Heuristic Programming in Scheduling Problem Using A* Algorithm

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Abstract: *In preparing the schedule of course not an easy job. There are several aspects that influence in the preparation of schedules of courses that professors, students, courses, lecture rooms, and a time slot. Each of these aspects has a state that can be a problem and a conflict in scheduling courses. For example, the problems facing aspect lecturers are lecturers conflict is a lecturer teaches courses scheduled at two different locations at a time. Or from the aspect of students, the problem is the number of classes per generation. In addition to these problems, there are many more potential problems that can arise from each of these aspects. A decision support system needed a model settlement of the problems encountered. To be able to determine the right model can be done by identifying problems and analyze environmental problems and identify variables that are involved in decision making. In scheduling the course, the problem is a complex problem that is solved by routine or repetitive. The complexity of the problem can be seen from every aspect in the preparation schedule of courses that are interconnected with other aspects. Then, the scheduling is done every semester by environmental circumstances different issues each semester. So that the right model for this system is a heuristic programming model.*

Keywords: *Artificial Intelligent, A*, Heuristic, Scheduling*

I. Introduction

Schedule subject is important in the lecture. Each department at the University has a schedule of courses structured so as to maintain the course of lectures in the department. Schedule subjects who either have equitable distribution of subjects per day for each level without obstacles in the lecture. In preparing the schedule of course not an easy job [1][4]. There are several aspects that influence in the preparation of schedules of courses that professors, students, courses, lecture rooms, and a time slot. Each of these aspects has a state that can be a problem and a conflict in scheduling courses. For example, the problems facing aspect lecturers are lecturers conflict is a lecturer teaches courses scheduled at two different locations at a time. Or from the aspect of students, the problem is the number of classes per generation. In addition to these problems, there are many more potential problems that can arise from each of these aspects [7].

To solve the problems mentioned above can be done in a way to build a computerized decision support system. The system will accept all of these issues as a matter of scheduling solutions structured to generate good courses [8]. The structured problem is a problem that it is possible to use the algorithm to understand the problem. By occupying algorithms or rules, it is possible to determine a replacement solution and evaluate it and determine the best solution.

A decision support system needs a model settlement of the problems encountered. The problems must be analyzed to identify the solution. In scheduling the course, the problem is a complex problem that is solved by routine or repetitive [3][5][6]. The complexity of the problem can be seen from every aspect in the preparation schedule of courses that are interconnected with other aspects. Then, the scheduling is done every semester by environmental circumstances different issues each semester. So that the right model for this system is a heuristic programming model [9].

According to George Polya, heuristic defined as the study of methods and rules of discovery. In preparing the schedule of the course, expressed as a heuristic rule to make a selection of the most time slots can be expected to reach acceptable solutions to problems. The time slot is like a path or trajectory to be traced by the courses that will be scheduled, so as to obtain the shortest path or trajectory to reach a solution is needed for an algorithm. An optimal algorithm to generate the shortest path or trajectory in finding a solution to the problem is the A* algorithm [9].

II. Related Work

The previous research tried to manage the schedule using genetic algorithms. Genetic algorithms is the optimal method to generate the schedule. The author did the evaluation at one of the universities in Medan, Indonesia. As the author noted in the Introduction, case studies taken in this study is the Faculty of Computer

Science, Universitas Pembangunan Panca Budi. For a schedule can be made correctly, there are some scheduling rules must be observed [9][10].

A. Courses Design

The author designed some criteria to determine the parameter used in the calculation. There are several factors affect the result of genetic algorithms. The factors that influence the preparation of the schedule to include are:

1. Lecturer

A professor can not teach several courses at the same time. Also, sometimes a teacher can only teach at odd hours and certain days only, so it is necessary to know the specific schedules that can not be subject to another.

2. Space

Given the limited amount of space owned, it should be noted the available space so as not to interfere with the course of the lecture. The schedule should only occupy space there.

3. Time

Time is a time limit of lectures per subject, and there are certain hours where the lecture is limited to certain hours such as Friday schedule from 07.30 until 12.00 and resumed at 13.30.

4. Course

Given each course has a semester of courses that are taught, the need for rules that restrict the scheduling of courses, so that the courses were by the rules of scheduling.

B. Genetic Step

Genetic step describes the sequence step to perform genetic algorithms. The model of genetic algorithm used in the research is described as follows:

1. Selection

In the selection, an assessment of the value of fitness. As a result, the fitness which has the best quality of chromosomes have a chance in the next generation. Selection used is the selection of the roulette wheel. In the implementation of this selection to consider the number of the population so that the population is not too much and take a long time, and the population is also not too little will result in chromosomal similarity.

2. Crossover

Crossover used was crossing one point with a permutation. Selection of chromosomes is determined by probability. Many genes are exchanged depends on the determination of the initial parameters. In doing a crossover, each of the two chromosomes will produce two new offspring as the best genes.

3. Mutation

Mutation is performed after the crossover operation is completed. This mutation technique is done by swapping genes randomly. In this process to consider the mutation rate and the degree of probability of a mutation. If the mutations are likely the best chromosome loss. However, if too little mutations, chromosome will long to find the optimal solution.

4. Determination of Fitness

Fitness determination is the provision of value that determines whether a process is achieved genetic algorithms What does this process is the process of making the schedule according to chromosome was selected by processing by calculating how close to the value of fitness

III. Proposed Work

A. Criteria Design

In the course scheduling, there are five criteria to be considered in scheduling courses that professors, students, rooms, subjects and time slots. Each of these criteria could cause problems in conducting the course scheduling. In preparing the schedule for the course, please note that each criterion has been linked with other criteria so that when scheduling a criterion to consider other criteria. For example, criteria for lecturers have a relationship with subject criteria for lecturers is a lecturer of the course. Another example is the criteria of the room with students who have the criteria of the relationship between the capacity of a room with some students from a class of students. To determine the relationship of the criteria mentioned above, it takes an explanation of each criterion to understand how the relationship of each of these criterias:

1. A lecturer can teach one or more subjects.
2. Students are people who are studying in colleges or universities. Students in a department consisting of several forces. Each batch consists of one or more classes of students. And each class of students comprising of some students attending from several subjects according to their level and their majors.
3. The room is the venue for a lecture from a course. A tuition discount room facilities are provided for the course lectures. One of the facilities is the principal seat student. The number of student seats or capacity (capacity) of the room will be an important consideration in building the course schedule. Also, there are some facilities that should be owned by a room which can also be taken into consideration in establishing the course schedule, such as multimedia equipment facilities.

4. A course is a unit of subjects taught at the college level. A minimum of subjects taught by a teacher and has several grade students taking the course by the level of the course.
5. The time slot is a subject allocate resources, faculty, students, and the room into a schedule that already comply with the limits specified.

Problems arise when scheduling courses is a conflict between the subjects, the rooms were available, and the number of time slots that can be used. In the case studies in this thesis, the conflict subjects that become a problem in scheduling and so to avoid a conflict of lecturers, students of class conflict, and conflict level course. Conflict lecturer in question is an incident in which a professor is lecturing at two or more different locations at any given time. Conflict freshman class is an incident in which a group of students scheduled to attend college classes at two or more locations at any given time while the level of conflict is the subject of an incident in which two or more subjects who have the same level scheduled at the same time.

B. Constrains

So that the system is capable of scheduling a course, it takes an ability to allocate all resources subjects, professors, students, and space into time slots with predetermined constraints. To achieve this, the ability to be filled with the knowledge of the limitations that exist in the hard constraints and soft constraints so that the system can cope with the problems encountered when scheduling course scheduling before the scheduled done. All criteria must comply definition on hard constraints and continued with checks on the definition there are a soft course schedule constraints after a solution is obtained. Each of these constraints, be it hard constraints and soft constraints have different restrictions. On the hard constraints, each must meet the criteria of the existing restrictions on such constraints. If there is one limitation of the constraints that can not be met, it is certain that these criteria can not be scheduled at the selected time slot. In contrast to the soft constraints, limitations given are not to be met by any criteria, but only as a reference for determining the quality of the resulting solution scheduling system later. Although all the criteria that have been scheduled can not meet the restrictions that exist in the soft constraints, these criteria are scheduled at the selected time slot. In addition to the knowledge of the limits of hard constraints and soft constraints. This subsystem also provides knowledge of a tree, looking for value conflict subjects, looking for value quality solutions course schedule and find the value of the effectiveness of scheduling a class. The tree will be used as a medium of the A * algorithm to find a time slot. Value conflict, of course, is used to determine the courses that will be scheduled in advance. Value quality solutions are used to determine the average fulfillment of each subject has been scheduled to restrictions on soft constraints while the effectiveness of scheduling courses Values used to determine the percentage of subjects who scheduled.

Hard Constraints

Based on the identification of a case study of this thesis and the problem of the criteria described in the preceding section, the boundaries of hard constraints are used in this system and must be met by all the criteria to establish a course schedule is as follows.

1. A professor can only give a lecture to one location at a certain time.
2. A professor can only give lectures according to the time availability of lecturers to teach.
3. A student can only attend classes for one location at a certain time.
4. A location (room) can only be used for one subject at a sufficiently specific time.
5. Students can not be allocated in one location that the number of students exceeds the capacity of the site.
6. Time lectures held every Monday through Saturday from 08:00 AM until 16:20 PM.
7. There is no tuition for all locations on Fridays at 12:10 pm until 13:00 pm.
8. The subjects that have the same level can not be scheduled at the same time.

Soft Constraints

Soft constraints are used as a reference for determining the quality of the course timetable solution within this system are as follows.

1. Minimize the occurrence of consecutive subjects schedule of subjects that have the same class of students. This constraint is used to prevent burnout and fatigue experienced by students when following the lecture. This constraint is also used to anticipate the movement of the lecture hall of a subject to another subject that has among classes considerable distance so as not to make students hassles at the turn of the course.
2. A course as much as possible not scheduled with the subjects that are one level below or above the level of the course at any given time together. This constraint can allow a student who wants to take a course one level above it so as to make it faster graduate students or allow students to take courses underneath to repeat subjects that failed previously.

3. Minimize the course schedule that causes a professor giving a lecture in a row. The constraint is intended to be a lecturer is not experiencing burnout and exhaustion in the lecture. On the system to be built, the boundaries of the three soft constraints above are only used as a determinant of the quality of the resulting solution lecture schedule after the hard constraints are applied to all resources subjects, professors, students, and the room. Value the quality of the course schedule is between 0 and 1, which will be expressed regarding percent (0-100%).

C. Tree

In the college search process, the system uses the tree as a medium of search. The tree is defined as an aggregation node / nodes with one special element called the root, and the other nodes are divided into sets of mutually unrelated to one another, or so-called subtree (Sanjaya, 2001). The tree has a size as much as 36 nodes with a depth of up to 8 levels. Each node contains a time slot that is different that represents the day and hour lecture. A* algorithm will search for the best time slot (lowest cost) for each of the subjects that will be scheduled by tracing nodes on a tree to obtain the desired solution.

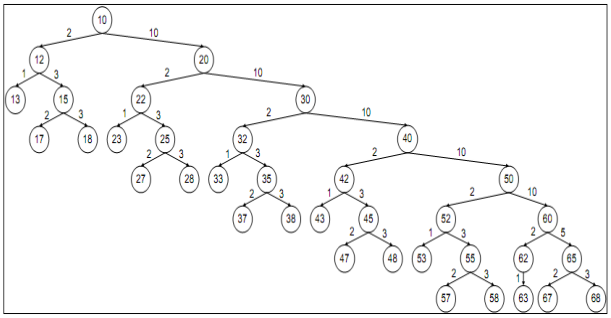

Fig. 1 Time Slot

Figure 1 describes the time slot. Each node contains a time slot representing the day and hour lecture. Figures dozens at nodes represent the lectures. Here's an explanation for the tens digit node time slot.

1. The number '1' represents Monday.
2. The number '2' represents Tuesday.
3. The number '3' represents Wednesday.
4. The number '4' represents Thursday.
5. The number '5' represents Friday.
6. The number '6' represents Saturday.

While the figures represent the unit at node lecture hours. Here's an explanation for the numbers on the unit node time slot.

1. The number '0' represents the first lecture (08.00 s.d. 8:50 pm).
2. The number '2' represents the third lecture (s.d. 09:40 pm 10:30 pm).
3. The number '3' represents the fourth lecture (10:30 s.d. 11:20 GMT).
4. The number '5' represents the sixth lecture (s.d. 12:10 pm 13:00 pm).
5. The number '7' represents the eighth lecture (s.d. 13:50 pm 14:40 pm).
6. The number '8' represents the ninth hour lecture (at 14:40 s.d. 15.30 pm).

Aside from being a manual day and hour lecture, the contents of the node also serve as the weight of the knot. And every knot of interrelated values that indicate the distance between the vertices. For example, the distance between the node '10' and '12' is 2. The weight distance between the node and the node will be used to find the value of f (n) in A* algorithm.

D. Error Value

There are nine boundaries hard constraints that must be fitted. To avoid conflicts between subjects, hard constraints will be a deterrent to these problems. Hard constraints provide restrictions on subjects that have lecturers, classroom students, and the level of the same subjects that are not scheduled for the same time slot. Such restrictions are contained within the limits of hard constraints H (1), H (3), and H (8). Limitations H (1) on the hard constraints have the function to avoid scheduling the courses that have the same lecturer scheduled for the same time slot. These are things that may happen in every department, in which a lecturer teaches two or more courses in the majors. To find out the conflict can be done by creating a matrix D = [DNM] This matrix

presents a conflict of subjects that have the same faculty. Where N is the number of subjects that will be scheduled and n, m = 1, ..., N.

$$D = \begin{bmatrix} d_{11} & d_{12} & d_{13} & \dots & d_{1m} \\ d_{21} & d_{22} & d_{23} & \dots & d_{2m} \\ d_{31} & d_{32} & d_{23} & \dots & d_{3m} \\ \dots & \dots & \dots & \dots & \dots \\ d_{n1} & d_{n2} & d_{n3} & \dots & d_{nm} \end{bmatrix}$$

Restrictions on H (3) on the hard constraints as limits on H (1) on the hard constraints. Restrictions on H (3) function to avoid scheduling the courses that have the same class of students is scheduled in the same time slot. A class of students may not be able to follow the course of more than one course at the same time. So that the subject can be followed by a class of students is concerned, must be scheduled at a different time slot. Thus, it can be said that the subjects that have the same class of students who are the subjects that conflict if it is scheduled in the same time slot. Such as limits on H (1), to determine the conflicts caused by the freshman class can be done by creating a matrix K = [KNM] This matrix NxN will present the courses that conflict because it has the same freshman class. N is the number of subjects that will be scheduled and n, m = 1, ..., N. and k are the value of conflict of subjects that have the same class of students.

$$K = \begin{bmatrix} k_{11} & k_{12} & k_{13} & \dots & k_{1m} \\ k_{21} & k_{22} & k_{23} & \dots & k_{2m} \\ k_{31} & k_{32} & k_{23} & \dots & k_{3m} \\ \dots & \dots & \dots & \dots & \dots \\ k_{n1} & k_{n2} & k_{n3} & \dots & k_{nm} \end{bmatrix}$$

Similarly, the limit of H (8). Conflicts that exist in the limit of H (8) can be determined by creating a matrix. Restrictions on H (8) is made to avoid scheduling the courses that have the same level scheduled for the same time slot. These limits will be able to function properly if the force of the students is divided into two or more classes of students in one class. If in one generation of students there is only one class of students, the limit on H (8) will be the same function as a limit on H (3). Restrictions on H (8) was formed with the aim that students have many alternatives in the electoral college. For example, a student wants to take a class lecture the next level up or redo a class. But the subject class schedule conflicts with the subjects that are required. With the course another class, the student can choose the subjects that the other classes as an alternative so that these students can take the course the next level up or redo a class. To find out the conflict due to limits on H (8) can be done by creating a matrix T = [TNM] This matrix NxN will present the courses that conflict because it has the same level of course. N is the number of subjects that will be scheduled and n, m = 1, ..., N and t nm is a value conflict of subjects n and m have the same level.

$$T = \begin{bmatrix} t_{11} & t_{12} & t_{13} & \dots & t_{1m} \\ t_{21} & t_{22} & t_{23} & \dots & t_{2m} \\ t_{31} & t_{32} & t_{23} & \dots & t_{3m} \\ \dots & \dots & \dots & \dots & \dots \\ t_{n1} & t_{n2} & t_{n3} & \dots & t_{nm} \end{bmatrix}$$

Value conflicts early on for all t nm is 0 and will add one if there is a conflict because the course n and m have the same course level. After the conflict of three matrix values is obtained, the third matrix are summed into a matrix C = [CLD] NxN, where C = D + K + T. This matrix will present the value conflicts between subjects that are caused by the lecturers, class, and level subjects, Value conflicts of matrix C will be the reference for scheduling. The subjects that have the greatest value of conflict will be scheduled in advance to maximize scheduling solution. Here is the algorithm flowchart of the matrix C = [CLD] NxN.

IV. Heuristic Programming

A. Heuristic Evaluation

The aTo build a heuristic programming model of decision support system that can solve the problem of scheduling course, necessary rules to address the problems of any scheduling criteria. The rules are made under restrictions that exist on the hard constraints and soft constraints. The rules will be formalized as heuristic that would be a decision rule that governs how a scheduling problem to be solved. Table 1 describes the criteria scheduling heuristics of subjects used as a model system.

Tabel 1 Heuristic

No	Schedule Criteria	Heuristics
1	Lecturer	Not to schedule a lecturer at a certain time if not by the time availability of lecturers.
2	Lecturer/ Room	No faculty member teaching the course for two different rooms or more at any given time.
3	Student / Room	No students who attend classes for two different rooms or more at any given time.
4	Student / Room	The number of students allocated to one room should be smaller than the capacity of the room.
5	Room/ Course	The room can only be used for one subject at a particular time.
6	Course	The subjects that have the same level can not be scheduled at the same time.
7	Course/ Room	Subjects who use projector allocated to one room which has projector facilities.
8	Time Slot	Time slot lectures held every Monday through Saturday from 08:00 pm until 16:20 pm
9	Time Slot	No lectures on Fridays at 12:10 pm until 13:00 pm (node '55').

Heuristic above will be combined with the A * algorithm in the process of scheduling the course by looking for time slots that meet the rules on the heuristic. However, not all existing heuristic above can be applied to all subjects. There are some subjects that are required to be immune to the rules of the decision. The course is a course that can do the course together despite having a class and level of the same course. The subjects in question are the subject of religion. Each course has a class of students and the level of the same subjects that should not be scheduled at the same time. But in practice, these courses can be scheduled at the same time slots even though the freshman class and the level of the same course. This is due to the students who complete the course are different for each matakuliahnya (depending on their respective religion) though the same class of students. Thus, in the process of finding a time slot, not all heuristic can be applied. To distinguish religious subjects with other subjects, the system uses the status of subjects, namely, the status of 'Normal' or 'Together.' The subjects that have the status of 'Normal' must meet all existing heuristic, while the religious subjects which have the status of 'Together' only meet some heuristic that is heuristic numbers 1, 4, 5, 7, and 9 in Table 4.1. In the implementation, heuristics above will be applied one by one to all the resources of all the subjects that will be scheduled. Steps in the application of heuristics that must be met for the subjects that have the status of 'Normal' is as follows:

1. Check whether the time slot to do lectures or not (H (7)), YES: proceed to number 2.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.
2. Check whether there is room in the time slot that is not used / empty (H (4)), if YES: go to 3a.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one..
3. Check (H (9)):

a. Are Subject Requires InFocus amenities, If YES: go to number 3b.NO: go to number 4a.
b. Is the room Having InFocus amenities, If YES: go to number 4a.NO: go to number 4b.

4. Check (H (5)):

a. Is the number of students from the class of subjects is smaller than the total capacity of the room, if YES: go to number 5. NO: go to number 4b.
b. Check whether there is still another empty room at that time slot, if YES: go back to 3a.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.

5. Check whether the courses that have been scheduled in that time slot does not have the same level with the subjects that are scheduled (H (8)), if YES: go to number 6. NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.
6. Check if the freshman class of subjects that have been scheduled in the time slot is not the same with the freshman class of the subjects that will be scheduled (H (3)), if YES: go to number 7. NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.

7. Check whether the professors who teach courses that are already scheduled for that time slot is not the same as the faculty member teaching the course to be scheduled (H (1)), ifYES: go to number 8.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.
8. Check whether the time slot is between the range of time availability of faculty to teach the courses that will be scheduled (H (2)), ifYES: Goal achieved.NO: subjects can not be scheduled in time slots.

While the steps in the application of heuristics that must be met for religious subjects which have the status of 'Together' is as follows:

1. Check whether the time slot to do lectures or not (H (7)), if YES: proceed to number 2.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.
2. Check whether there is room in the time slot that is not used or empty (H (4)), ifYES: go to 3a.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.
3. Check (H (9)):

a. Does the course require InFocus facilities, ifYES: go to number 3b.NO: go to number 4a.
b. Does the room have facilities InFocus, ifYES: go to number 4a.NO: go to number 4b.

4. Check (H (5)):

a. Is the number of students from the class of subjects is smaller than the number of room capacity, ifYES: go to number 5.NO: go to number 4b.
b. Check whether there is still another empty room at that time slot, ifYES: go back to 3a.NO: subjects can not be scheduled in the time slot, move to the next time slot and get back to number one.

5. Check whether the time slot is between the range of time availability of faculty to teach the courses that will be scheduled (H (2)), ifYES: Goal achieved.NO: subjects can not be scheduled in time slots.

B. Heuristic Algorithms

An algorithm is a sequence of steps necessary logic to problem solving and programming. The algorithm used to analyze and explain the sequence and relationship of activities that will be pursued. The preparation of this algorithm is very important in the design of a program. Besides algorithms also serve to resolve the problems to achieve a goal. The algorithm of this system are as follows:

Algorithms for Finding Lecturer Conflict

```
Start
Input
n,m = course count
Output
Save D[i,j]
Procces
For i=1 to n step 1
        For m j=1 to m step 1
            D[i,j] = 0
            Lecturer[i] = lecturer for course i
            Lecturer[j] = lecturer for course j
        Next
        if Lecturer [i] = Lecturer [j]then
            D[i,j] = D[i,j] + 1
            Save D[i,j]
        Else
            Exit
        End
Next
```

Algorithms for Finding Class Conflict

```
Start
Input
n,m = course count
Output
Save D[i,j]
Procces
For i=1 to n step 1
For m j=1 to m step 1
```

```
D[i,j] = 0
Class[i] = class for course i
Class[j] = class for course j
Next
if Class [i] = Class [j]then
        D[i,j] = D[i,j] + 1
        Save D[i,j]
Else
        Exit
End
Next
```

Algorithms for Finding Level Conflict

```
Start
Input
n,m = course count
Output
Save D[i,j]
Procces
For i=1 to n step 1
For m j=1 to m step 1
D[i,j] = 0
Level[i] = level for course i
Level [j] = level for course j
Next
if Level [i] = Level [j]then
        D[i,j] = D[i,j] + 1
        Save D[i,j]
Else
        Exit
End
Next
```

Algorithms for Finding Course Conflict

```
Start
Input
n,m = course count
Output
Save k as conflict value for course i
Procces
For i=1 to n step 1
k = 0
For j=1 to m step 1
D[i,j], K[i,j], T[i,j]
C[i,j] = 0
C[i.j] = D[i,j] + K[i,j] + T[i,j]
k = k + C[i,j]
Next
        Save k as conflict for course i
Next
```

V. Conclusion

From the calculations above it can be concluded that the scheduling system subjects with heuristic programming model using the A* algorithm produces solutions schedule courses that can be taken into consideration in the decision to build the course schedule. This study provides a quality assessment solutions course schedule is generated based on the fulfillment of the limitations on the soft constraints. This system provides a value that indicates the degree of effectiveness of how many courses that can be scheduled by the system of resource you want to schedule courses.

VI. Future Scope

Based on the research and implementation of the system is done, it can be given some suggestions. The timing of the availability of faculty to teach a class of subjects should be avoided accumulation of data lecturers same timing to prevent possible conflicts of courses. In choosing the time availability of faculty teaching, should not select more than one time lecturers because the system only uses the time availability of lecturers. Users were expected to consider the schedule for the course together because the system can not control the number of students to grade students combined so feared overload areas that are used. If there are subjects that are not scheduled, the user should find out the causes why these courses can not be scheduled because the system can not provide information as to why the course is not scheduled.

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