International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

# Using Graph Coloring for University Timetable Problem

**R. Kristoforus J. Bendi[1], Theresia Sunarni[2], Achmad Alfian[3]**

[1, 2, 3]Musi Charitas Catholic University, Faculty of Science and Technology, No. 60 Bangau Road, Palembang 30113, Indonesia

**Abstract:** ***Univeristy Timetabling is a way of allocating students who take courses, lecturers who teach courses, and space used for lectures at available time slots. The problem that often arises in the lecture scheduling process is the occurrence of clash of subjects because lecturers or students with the same semester are scheduled in the same time slot, and violations occur in scheduling the lecturers' requests not to be scheduled at certain time slots. For this reason, the scheduling of courses needs to be improved to optimize the available resources. The technique of graph node coloring with the Welsh Powell algorithm was chosen as the starting method in this study. With the graph coloring technique each event will be calculated the degree of connection with other events and then given a certain color based on the order of degrees. After that each event will be placed sequentially into a time period based on the priority of the restrictions made. The results of the study show that coloring is the basis for allocating time and space slots in the scheduling process. In this study the process was made in 2 scenarios with different sessions available, available space, and available days. The two scenarios show that with scenario 2 time slots, 4 spaces, and 5 days get optimal results where constraint violations occur at least and the level of space utilization is greater.***

**Keywords:** university timetabling, graph coloring, welsh-powell algorithm**.**

## 1. Introduction

University Timetable Problems (UTP) have become one of the research topics that have been widely conducted [1, 2, 3]. Jat & Yang [4] states that UTP is a multidimensional allocation issue, where students and lecturers are allocated in courses, subject classes and time preferences (both lecturers and students) are allocated in classrooms and time slots (timeslots). UTP is a type of time allocation problem that is solved by evaluating the limits given.

Lecture scheduling is a routine activity conducted every semester at a college. Lecture scheduling is a way of allocating students who take courses, lecturers who teach courses, and space used for lectures at available time slots. Lecture activities are carried out by considering the number of lecturers and classrooms and available time slots.

Often in the process of arranging the lecture schedule there are conflicts or clashes between courses, lecturers, or lecture rooms at a certain time slot. This can be caused by several things, including: (a) a lecturer teaching several different subjects, (b) using the same room for different subjects, (c) the limited number of lecture rooms available, (d) needs certain rooms (specifically) for several courses, and (e) the request of the lecturer concerned not to teach at a certain time slot. The preparation of the lecture schedule in the Informatics study program and study program of the Faculty of Science and Technology Information System, Musi Charitas Catholic University (MCCU) also still faces obstacles in the occurrence of clashes and the failure of lecturers' requests not to be scheduled at certain time slots. Scheduling is done by placing certain subjects in a certain space and time slot, then for other courses by looking for time slots that are still empty. Scheduling carried out by trial and error like this will certainly be difficult and requires a long time because they have to make repetitions repeatedly.

## 2. Literature Review

There are various scheduling methods that have been developed before. Burke & Sanja [5] state that there are at least four groups of methods that have been used in various studies, including sequential methods, cluster methods, constructional based methods, and meta-heuristics. One method that is often used for lecture scheduling problems is the graph coloring method. This technique is included in the group of sequential methods.

Graph coloring places the occurrence of each event sequentially into a valid time period such that there is no conflict between events. This technique uses graph representation, where events are represented as vertices and conflict is represented as a path / node (Burke & Petrovic, 2002). Some previous studies have shown that the algorithm often used in graph coloring is the Welch-Powell algorithm [2, 6, 7, 8, 9, 10, 11, 12]. Graph (graph) is a discrete structure consisting of vertices and edges, or in other words, a graph is a set of pairs (V, E) with V is a non-empty set of vertices and E is a set of sides connecting a pair node in the graph. Figure 1 is an example of drawing vertices, sides and calculation of degrees. In picture 1, there are 4 subjects (01, 02, 03, and 04) with connecting lines (sides) between subjects which show the similarity of lecturers and semesters. The degree of node is calculated based on the number of sides a node has. The degree of vertex 01 is 2, node 02 is 3, node 03 is 2, and node 04 is 3.

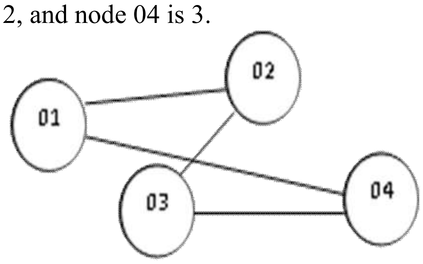


**Figure 1:** Sample of Graph

In graph theory, the term graph coloring is known as a method for labeling a graph. The label can be given to vertices, sides or regions (Astuti, 2011). The vertex coloring of a graph is to color the vertices of a graph so that no two neighboring nodes have the same color. We can give any color to the nodes as long as they are different from the neighboring nodes.

Welch Powell algorithm is one of the graph coloring algorithms that performs coloring based on the highest degree of vertices, called Largest Degree Ordering (LDO). The Welch Powell algorithm can be used to color a G graph efficiently and practically, although it does not always provide the minimum number of colors needed to color G. The coloring stages with Welch Powell algorithm are as follows:

1) Sort the vertices of G in decreasing degrees
2) Use one color to color the first node (which has the highest degree) and other vertices (in sequential order) that are not adjacent to this first node.
3) Start again with the next highest degree node in the sorted list that has not been colored and repeat the node coloring process using the second color.
4) Repeat using colors until all the vertices have been colored.

## 3. Research Methodology

The stages to be carried out in this study are (1) data collection and codification, (2) graph coloring process, (3) time slot allocation, and (4) optimization analysis. The stages in scheduling begin collecting and codifying data. In the next stage, identification of relationships between vertices in this case is conducted, based on the similarity of lecturers, study programs and semesters. The relationship formed becomes the basis for calculating the degree of courses used in graph coloring. Next the results of graph coloring become the basis for allocating time and space slots on the schedule. Allocations are carried out with due regard to predetermined contraints. At this stage, the allocation process is carried out in two scenarios. The final step is to compare the results of allocations based on predetermined scenarios to see the most optimal results.

## 4. Analysis and Result

### 4.1 Data Collections

The data used in this study are 2016/2017 semester semester lecture data on Informatics study programs and Information Systems study programs, Catholic University of Musi Charitas (Table 2). There are 39 courses with 18 lecturers. The total credits for all courses are 112 credits or 56 lecture sessions, where 2 credits will be held in each lecture session. The total courses that use the laboratory are 48 credits or 24 sessions that need to be carried out in the laboratory (Table 2). There are 4 laboratories used. The remaining 32 lecture sessions were held in the lecture hall. Lecture rooms are available in 3 rooms.

To facilitate data processing, data codification is first done. Each data will be represented numerically based on the provisions provided (Table 1).

**Table 1:** Data Codefication

| *Criteria Representation* | *Code* | *Description* |
|---|---|---|
| Course | 1 to 39 | each subject of course are represented by a number. For example MK001 will be coded 1, and so on. |
| Lecturer | 1 to18 | each lecturer is represented by a number. For example lecturer D001 will be coded 1, and so on. |
| Credit | 2 or 4 | 2 = courses with a load of 2 credits, 4 = courses with a load of 4 credits |
| Department | 1 to 3 | 1 = informatics department (IF), 2 = information systems department (SI), 3 = joint class of IF and SI |
| semester | 1 to 8 | 1 = the first semester 1, 2 = the second semester and so on. |

### 4.2 Graph Coloring Process

After the data codification is done, the next step is to do graph coloring. In this case, the course is the vertex of the graph, while the lecturer, study program and semester become the edge connecting one node with another node. Each subject taught by the same lecturer is considered to have a related side. Likewise if the subject is in one study program and the same semester will be considered to have a related side.

The first stage in graph coloring is to calculate the number of sides or degrees of each vertex. For example, MK001 will have a side connected to MK009 and MK016 because it is administered by the same lecturer, namely D007. MK001 will also have sides connected with MK023, MK024, MK025 and MK039 because the five subjects are in one department (SI) in the same semester (semester 1). In addition MK001 will also be connected to MK006, MK007, MK014, and MK015 because the four subjects are IF and SI combined courses. Thus MK001 will have 10 sides that are connected to another node or given a degree value = 7. Another example, MK002 is a joint course of IF and SI department in semester 3. Thus MK002 will be connected to MK001, MK010, MK018, MK019 courses , as well as joint IF / SI courses (MK006, MK007, MK014, MK015). Thus MK002 will have a degree value = 8.

**Table 2:** Data Collection

| *No* | *Course* | *Lecture* | *Department* | *credits* | *Semester* | *Node of graph* |
|---|---|---|---|---|---|---|
| 1 | 01 | 07 | 2 | 4 | 1 | 01/07/2/4/1 |
| 2 | 02 | 08 | 3 | 2 | 3 | 02/08/3/2/3 |
| 3 | 03 | 13 | 2 | 4 | 5 | 03/13/2/4/5 |
| 4 | 04 | 13 | 1 | 4 | 5 | 04/13/1/4/5 |
| 5 | 05 | 14 | 1 | 4 | 7 | 05/14/1/4/7 |
| 6 | 06 | 10 | 3 | 2 | 7 | 06/10/3/2/7 |
| 7 | 07 | 01 | 3 | 2 | 7 | 07/01/3/2/7 |
| 8 | 08 | 09 | 1 | 4 | 5 | 08/09/1/4/5 |
| 9 | 09 | 07 | 1 | 4 | 5 | 09/07/1/4/5 |
| 10 | 10 | 05 | 2 | 2 | 3 | 10/05/2/2/3 |
| 11 | 11 | 06 | 1 | 4 | 3 | 11/16/1/4/3 |
| 12 | 12 | 02 | 2 | 2 | 5 | 12/02/2/2/5 |
| 13 | 13 | 10 | 2 | 2 | 6 | 13/10/2/2/6 |

| No | Course | Lecture | Department | credits | Semester | Node of graph |
|---|---|---|---|---|---|---|
| 14 | 14 | 10 | 2 | 4 | 1 | 14/10/2/4/1 |
| 15 | 15 | 14 | 2 | 2 | 6 | 15/14/2/2/6 |
| 16 | 16 | 07 | 1 | 4 | 8 | 16/07/1/4/8 |
| 17 | 17 | 11 | 2 | 4 | 5 | 17/11/2/4/5 |
| 18 | 18 | 11 | 1 | 4 | 5 | 18/11/1/4/5 |
| 19 | 19 | 06 | 2 | 2 | 3 | 19/06/2/2/3 |
| 20 | 20 | 06 | 1 | 2 | 3 | 20/06/1/2/3 |
| 21 | 21 | 06 | 3 | 2 | 3 | 21/06/3/2/3 |
| 22 | 22 | 17 | 3 | 2 | 3 | 22/17/3/2/3 |
| 23 | 23 | 03 | 2 | 2 | 1 | 23/03/2/2/1 |
| 24 | 24 | 15 | 2 | 4 | 1 | 24/15/2/4/1 |
| 25 | 25 | 10 | 2 | 2 | 1 | 25/10/2/2/1 |
| 26 | 26 | 02 | 2 | 2 | 5 | 26/02/2/2/5 |
| 27 | 27 | 09 | 2 | 2 | 7 | 27/09/2/2/7 |
| 28 | 28 | 10 | 2 | 2 | 3 | 28/10/2/2/3 |
| 29 | 29 | 04 | 1 | 4 | 5 | 29/04/1/4/5 |
| 30 | 30 | 02 | 2 | 4 | 5 | 30/02/2/4/5 |
| 31 | 31 | 14 | 1 | 2 | 6 | 31/14/1/2/6 |
| 32 | 32 | 18 | 2 | 2 | 5 | 32/18/2/2/5 |
| 33 | 33 | 02 | 2 | 2 | 7 | 33/02/2/2/7 |
| 34 | 34 | 10 | 2 | 2 | 3 | 34/10/2/2/3 |
| 35 | 35 | 15 | 1 | 2 | 3 | 35/15/1/2/3 |
| 36 | 36 | 05 | 2 | 4 | 3 | 36/05/2/4/3 |
| 37 | 37 | 16 | 1 | 4 | 3 | 37/16/1/4/3 |
| 38 | 38 | 09 | 3 | 2 | 3 | 38/09/3/2/3 |
| 39 | 39 | 12 | 2 | 4 | 1 | 39/12/2/4/1 |

After the degree of each subject is calculated, the next step is to give color to each subject starting from the subject with the highest degree. After that, the same color will be given to all courses that do not have sides with courses that have been colored. For example, MK006 is a node with the highest degree, then MK006 will be colored 1. After that all nodes that have no side are connected to MK006. All nodes that do not have a side connected to MK006 will be the same color as MK006, i.e. color 1. The next step selects the node with the next highest degree that has not been colored. In this case MK014 will be selected as the node to be colored. MK014 will be given color 2. Then all nodes that are not side by side with MK014 will be searched for given the same color. The process is done repeatedly until all the vertices get color. Table 3 presents the degrees of each course and the results of the coloring.

**Table 3:** Degree and Color of Node

| No | Course | Degree | Color |
|---|---|---|---|
| 1 | 01 | 10 | 5 |
| 2 | 02 | 8 | 5 |
| 3 | 03 | 5 | 8 |
| 4 | 04 | 6 | 5 |
| 5 | 05 | 7 | 5 |
| 6 | 06 | 17 | 1 |
| 7 | 07 | 12 | 4 |
| 8 | 08 | 3 | 5 |
| 9 | 09 | 7 | 5 |
| 10 | 10 | 10 | 5 |
| 11 | 11 | 6 | 5 |
| 12 | 12 | 8 | 5 |
| 13 | 13 | 12 | 5 |
| 14 | 14 | 17 | 2 |
| 15 | 15 | 14 | 3 |
| 16 | 16 | 5 | 5 |
| 17 | 17 | 6 | 5 |
| 18 | 18 | 9 | 5 |
| 19 | 19 | 10 | 5 |
| 20 | 20 | 6 | 6 |
| 21 | 21 | 6 | 6 |
| 22 | 22 | 7 | 6 |
| 23 | 23 | 7 | 6 |
| 24 | 24 | 8 | 6 |
| 25 | 25 | 8 | 7 |
| 26 | 26 | 8 | 5 |
| 27 | 27 | 4 | 6 |
| 28 | 28 | 10 | 6 |
| 29 | 29 | 5 | 5 |
| 30 | 30 | 7 | 6 |
| 31 | 31 | 3 | 5 |
| 32 | 32 | 4 | 6 |
| 33 | 33 | 3 | 6 |
| 34 | 34 | 5 | 9 |
| 35 | 35 | 5 | 10 |
| 36 | 36 | 5 | 5 |
| 37 | 37 | 6 | 5 |
| 38 | 38 | 7 | 5 |
| 39 | 39 | 4 | 6 |

### 4.3 Slot Allocations

The first step in the allocation process is to determine the lecturer time preference and course preference. What is meant by lecturer time preference is the time available for a lecturer. While the subject space preferences are courses that need or must be carried out in certain spaces, for example practicum courses must be carried out in the laboratory. Preference determination is needed to determine slot allocation priorities. Table 4 shows the lecturer time preference. While Table 5 shows the preferences of the course space.

**Table 4a:** Lecturer Preferences

| No | Lecturer | Monday | | | Tuesday | | | Wednesday | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 01 | | v | v | | | v | | v | v |
| 2 | 02 | v | v | v | v | v | v | v | v | v |
| 3 | 03 | | v | v | | v | v | | v | v |
| 4 | 04 | | | | | | | | | |
| 5 | 05 | v | v | v | v | v | v | v | v | v |
| 6 | 06 | v | v | v | v | v | v | v | v | v |
| 7 | 07 | v | v | v | v | v | v | v | v | v |
| 8 | 08 | v | v | | v | v | | v | v | |
| 9 | 09 | v | v | v | v | v | v | v | v | v |
| 10 | 10 | v | v | v | v | v | v | v | v | v |
| 11 | 11 | v | v | v | v | v | v | v | v | v |
| 12 | 12 | v | v | | v | v | | v | v | |
| 13 | 13 | | | | | | | | | |
| 14 | 14 | v | v | v | v | v | v | v | v | v |
| 15 | 15 | v | v | | v | v | | v | v | |
| 16 | 16 | v | v | v | v | v | v | v | v | v |
| 17 | 17 | | | | | | | | | |
| 18 | 18 | v | v | v | v | v | v | v | v | v |

**Table 4b:** Lecturer Preferences

| *No* | *Lecturer* | *Thursday* | | | *Friday* | | | *Saturday* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *1* | *2* | *3* | *1* | *2* | *3* |
| 1 | 01 | | | v | | v | v | | | |
| 2 | 02 | v | | | v | v | v | | | |
| 3 | 03 | v | v | | v | v | | | | |
| 4 | 04 | v | v | v | | | | | | |
| 5 | 05 | v | | | v | v | v | | | |
| 6 | 06 | v | | | v | v | v | | | |
| 7 | 07 | v | | | v | v | v | | | |
| 8 | 08 | | | | v | v | | | | |
| 9 | 09 | v | | | v | v | v | | | |
| 10 | 10 | v | | | v | v | v | | | |
| 11 | 11 | | | | v | v | | | | |
| 12 | 12 | v | v | | v | v | | | | |
| 13 | 13 | v | v | v | | | | v | v | |
| 14 | 14 | | | | v | v | v | | | |
| 15 | 15 | v | | | v | v | | | | |
| 16 | 16 | v | | | v | v | | | | |
| 17 | 17 | v | | | v | | | v | v | v |
| 18 | 18 | | | | v | v | v | | | |

Courses will be allocated into time slots based on constraints or specified scheduling limits. There are two types of constraints that are determined, namely hard constraint and soft constraint. Hard constraint is a limitation that must be met or may not be violated at the time of preparing the schedule. While soft constraints are boundaries that are fulfilled as much as possible. Hard constraints in this study are as follows.

1) A lecturer cannot be scheduled at the same time for two or more courses.
2) A course cannot be scheduled together with other courses that coincide with the semester in the same study program
3) A course scheduled for a particular space can only be carried out in that space.

**Table 5:** Room Preferences

| *Course* | *Room* |
|---|---|
| 01 | L1 |
| 03 | L4 |
| 04 | L4 |
| 08 | L5 |
| 09 | L5 |
| 10 | L2 |
| 11 | L2 |
| 16 | L5 |
| 17 | L1 |
| 18 | L1 |
| 21 | L5 |
| 36 | L4 |
| 37 | L4 |
| 38 | L5 |

While soft constraints are used as follows.

1) A lecturer is tried to be scheduled according to the available time preferences
2) Courses with the same semester are scheduled for a maximum of 2 courses per day.

At the time of allocation, data is placed in priority based slots. The allocation priority is as follows.

1) The combined course will be scheduled in advance.
2) Lecturers with the least time preference will be scheduled first.
3) Courses with preferences for specific space requirements will be scheduled in advance.
4) Courses with a higher semester will be scheduled in advance.
5) Courses with a higher number of credits will be scheduled in advance.

Because the process of filling courses into slots is a sequential process, the next step is to determine the order of subjects to be allocated into the time slot. Determination of the sequence of courses is carried out by the following steps: (1) starting from the smallest color, for example starting from color = 1 and so on, (2) for all courses selected in step (1), select the subject with the smallest lecturer preference , (3) for all courses selected in step (2), select the subject with a specific space preference, (4) for all courses selected in step (3), select the highest semester course, (5) for all courses selected in step (4), select the subject with the highest score, (6) for all courses selected in step (5), select the course with the smallest course code, (7) place the chosen course in step (6) in the first order and so on, (8) go back to step (2) until all courses with color = 1 are finished sorting, (9) back to step (1). Sorting results can be seen in Table 3.

During the slot filling process, the first step is to design a slot scenario. In this analysis two scenarios were used (Table 6). Determination of this scenario is based on the amount of data that must be allocated. Of the 56 lecture sessions there are 18 sessions that must be allocated to special rooms, while the remaining 38 sessions need to be allocated in the classroom. Therefore, the time slot provided is at least 56 slots, with a minimum of 18 special space slots and 38 slots for classrooms.

**Table 6:** The Scenarios

| *Scenario* | *Number of Days* | *Number of Class Rooms* | *Number of Spesific Rooms* | *Number Sessjon/day* |
|---|---|---|---|---|
| 1 | 5 | 4 | 4 | 2 |
| 2 | 5 | 3 | 4 | 3 |

The process of allocating data into slots is the process of filling session and space matrix cells. The cell filling process is carried out sequentially starting from the first cell and so on by paying attention to the lecturer preferences, space preferences and defined contraints. The results of the subject allocation can be seen in Table 7 and Table 8.

**Table 7:** The Result of First Scenario

| *Slots* | | *T1* | *T2* |
|---|---|---|---|
| Monday | R1 | 06/10/3/2/3 | 14/10/3/2/3 |
| | R2 | 31/14/2/2/6 | 39/12/1/4/5 |
| | R3 | 39/12/1/4/5 | 33/02/1/4/8 |
| | R4 | 27/09/1/4/7 | 35/15/3/2/7 |
| | L1 | 17/11/2/4/1 | 17/11/2/4/1 |
| | L2 | 11/16/2/2/5 | |
| | L4 | | 37/16/2/2/5 |
| | L5 | 16/07/2/2/7 | 08/09/2/2/6 |
| Tuesday | R1 | 15/14/3/2/3 | 02/08/2/2/3 |
| | R2 | 12/02/2/4/5 | 05/14/2/2/1 |
| | R3 | 32/18/1/4/5 | 12/02/2/4/5 |
| | R4 | 27/09/1/4/7 | 34/10/1/2/6 |

| *Slots* | | *T1* | *T2* |
|---|---|---|---|
| | L1 | | |
| | L2 | | |
| | L4 | 36/05/2/2/1 | 03/13/3/2/7 |
| | L5 | | 21/06/1/4/5 |
| Wednesday | R1 | 26/02/2/4/5 | 07/01/3/2/3 |
| | R2 | 24/15/1/4/3 | 26/02/2/4/5 |
| | R3 | 32/18/1/4/5 | 20/06/1/4/5 |
| | R4 | 25/10/2/2/7 | |
| | L1 | 18/11/2/2/3 | |
| | L2 | | |
| | L4 | | |
| | L5 | 38/09/2/4/1 | 38/09/2/4/1 |
| Thursday | R1 | 29/04/2/4/1 | 29/04/2/4/1 |
| | R2 | 22/17/1/4/3 | 23/03/1/2/3 |
| | R3 | 33/02/1/4/8 | ***20/06/1/4/5*** |
| | R4 | 28/10/2/4/5 | |
| | L1 | | ***01/07/2/2/3*** |
| | L2 | 10/05/2/2/3 | |
| | L4 | | |
| | L5 | 21/06/1/4/5 | |
| Friday | R1 | 19/06/2/4/3 | 19/06/2/4/3 |
| | R2 | 22/17/1/4/3 | 24/15/1/4/3 |
| | R3 | 30/02/1/4/5 | 28/10/2/4/5 |
| | R4 | 13/10/1/2/3 | 30/02/1/4/5 |
| | L4 | ***04/13/2/4/1*** | ***04/13/2/4/1*** |
| | L5 | 09/07/2/2/5 | |

### 4.4 Optimization Analisys

Table 7 shows the results of slot allocation for scenario 1. Based on Table 7, it appears that there are violations of soft constraints which are indicated by the existence of courses placed not in accordance with the lecturers' time preferences (20/06/1/4/5, 01/07/2 / 2/3, 04/13/2/4/1, 04/13/2/4/1). In scenario 2 (Table 8), it can be seen that soft constraint violations occur in one course (04/13/2/4/1).

**Table 8:** The Result of Second Scenario

| *Slots* | | *T1* | *T2* | *T3* |
|---|---|---|---|---|
| Monday | R1 | 06/10/3/2/3 | 14/10/3/2/3 | 15/14/3/2/3 |
| | R2 | 31/14/2/2/6 | 39/12/1/4/5 | 05/14/2/2/1 |
| | R3 | 39/12/1/4/5 | 33/02/1/4/8 | 12/02/2/4/5 |
| | L1 | 17/11/2/4/1 | 17/11/2/4/1 | |
| | L2 | 11/16/2/2/5 | | |
| | L4 | | 37/16/2/2/5 | |
| | L5 | 16/07/2/2/7 | 08/09/2/2/6 | 21/06/1/4/5 |
| Tuesday | R1 | 02/08/2/2/3 | 12/02/2/4/5 | 07/01/3/2/3 |
| | R2 | 26/02/2/4/5 | 24/15/1/4/3 | 26/02/2/4/5 |
| | R3 | 13/10/1/2/3 | 32/18/1/4/5 | 23/03/1/2/3 |
| | L1 | | 18/11/2/2/3 | |
| | L2 | | | |
| | L4 | 36/05/2/2/1 | | |
| | L5 | 21/06/1/4/5 | 38/09/2/4/1 | 38/09/2/4/1 |
| Wednesday | R1 | 19/06/2/4/3 | 32/18/1/4/5 | 19/06/2/4/3 |
| | R2 | 24/15/1/4/3 | 27/09/1/4/7 | 27/09/1/4/7 |
| | R3 | 30/02/1/4/5 | 28/10/2/4/5 | 28/10/2/4/5 |
| | L1 | | | |
| | L2 | | | |
| | L4 | ***04/13/2/4/1*** | | |
| | L5 | 09/07/2/2/5 | 10/05/2/2/3 | |
| Thursday | R1 | 29/04/2/4/1 | 29/04/2/4/1 | |
| | R2 | 22/17/1/4/3 | | |
| | R3 | 20/06/1/4/5 | | |
| | L1 | 01/07/2/2/3 | | |
| | L2 | | | |
| | L4 | 03/13/3/2/7 | | 04/13/2/4/1 |
| | L5 | | | |
| Friday | R1 | 22/17/1/4/3 | 30/02/1/4/5 | 25/10/2/2/7 |
| | R2 | 20/06/1/4/5 | 34/10/1/2/6 | |
| | R3 | 35/15/3/2/7 | 35/15/3/2/7 | |

Based on these two scenarios, optimization analysis is then carried out. Analysis is based on the number of constraint violations and time slot utilization. The results of the analysis (Table 9) show that scenario 1 is more optimal compared to scenario 2. This shows that although soft constraints occur in scenario 1, time slots utilization is more efficient.

**Table 9:** Utilization Analysis

| *Scenario* | *hard constraints violations* | *soft constraints violations* | *utilization* |
|---|---|---|---|
| 1 | 0% | 7,1% | 36,8% |
| 2 | 0% | 3,6% | 29,5% |

## 5. Conclusions

The results of the study show that graph coloring with the Welch Powell algorithm can be used to produce class schedules. Further research needs to be done to optimize the scheduling results that have been obtained. Thus, it is expected that all the contraints set can be fulfilled. This research will continue with scheduling with a wider scope and software will be made for scheduling with graph coloring using the Welch-Powell algorithm.

## 6. Acknowledgement

This article is part of the 2018 National Institutional Strategic Research Grant Program funded by the Directorate of Research and Community Service, Directorate General of Higher Education. Our thanks go to all respondents who have provided data. Also for leaders and colleagues at the Musi Charitas Catholic University for their enthusiasm.

## References

[1] Dewi, F. K., 2010, "Pembangunan Perangkat Lunak Pembangkit Jadwal Kuliah dan Ujian Dengan Metode Pewarnaan Graf", Buana Informatika, Vol 1 No1, hlm. 57-68.

[2] Hiryanto, L., & Thio, J. S., 2011, "Pengembangan Metode Graph Coloring Untuk University Course Timetable Problem Pada Fakultas Teknologi Informasi Universitas Tarumanagara", Jurnal Ilmu Komputer dan Informasi, Vol 4 No 2, hlm. 82-91.

[3] Lumbantoruan, I., 2014, "Perancangan Aplikasi Penjadwalan Bimbingan Belajar Dina Education Center Menggunakan Metode Welch Powell. Pelita Informatika Budi Darma", Vol 7 No 2, hlm. 141-146. Diambil kembali dari http://www.pelita-informatika.com/berkas/jurnal/24.%20imelda.pdf

[4] Jat, S. N., & Yang, S., 2008, "A Memetic Algorithm for the University Course Timetabling Problem", IEEE International Conference on Tools With Artificial Intelligence, hlm. 427-433, IEEE.

[5] Burke, E. K., & Petrovic, S., 2002, "Recent Research Directions In Automated Timetabling", European Journal of Operational Research , hlm. 266-280.
[6] Astuti, S., 2011, "Penyusunan Jadwal Kuliah Dengan Algoritma Pewarnaan Graf Welch Powell", Jurnal Dian, Vol. 11 No1, hlm. 68-74.
[7] Bozyer, Z., Basar, M. S., & Aytekin, A., 2011, "A Novel Approach of Graph Coloring for Solving University Course Timetabling Problem", The Second International Symposium on Computing in Science & Engineering, hlm. 560-566, Kusadasi, Aydin, Turkey: Gediz University Publications.
[8] Cauvery, N. K., 2011, "Timetable Scheduling using Graph Coloring", International Journal of P2P Network Trends and Technology, Vol 1 No 2, hlm. 57-62.
[9] Dandashi, A., & Al-Mouhamed, M., 2010, "Graph Coloring for Class Scheduling", IEEE/ACS International Conference on Computer Systems and Applications, hlm. 1-4, Hammamet: IEEE.
[10] Qu, R., Burke, E. K., McCollum, B., Merlot, L. T., & Lee, Y. S., 2009, "A Survey of Search Methodologies and Automated System Development for Examination Timetabling", Journal of Scheduling, hlm. 55-89.
[11] Susiloputro, A., Rochmad, & Alamsyah., 2012, "Penerapan Pewarnaan Graf Pada Penjadwalan Ujian Menggunakan Algoritma Welsh Powell", UNNES Journal Of Mathematics, Vol 1 No 1, hlm. 1-7.
[12] Tasari, 2012, "Aplikasi Pewarnaan Graf Pada Penjadwalan Perkuliahan Di Program Studi Pendidikan Matematika Unwidha Klaten", Magistra, No 82 Th 24 Desember 2012, hlm.70-78.