



Application of Graph Coloring in the Course Scheduling Case of Mathematics Education Department in Unai

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ABSTRACT

Courses scheduling is a very important activity in the teaching and learning process in the Mathematics Education Department. The teaching and learning process is carried out by all students and lecturers, so that the schedule of courses arranged must benefit the lecturers and students. If some of the provisions in scheduling are not properly calculated, it will cause difficulty during the scheduling process. These provisions include courses held, number of classes available, amount of time available, number of students taking and availability of lecturers who teach. This study aims to create an automation on the course scheduling using six stages FAST Methodology which includes Scope Definition, Problem Analysis, Requirement Analysis, Logical Design, Decision Analysis, Physical Design and Integration. The Welsh-Powell algorithm has used which is one of the algorithms in the graph coloring method and implemented using C ++ programming. The results of the study show that the programme is able to provide a quick and accurate solution for setting up course schedules. The results of this study can provide convenience in managing the right courses scheduling so that it helps the courses scheduling process to be even better.

Keywords: Course schedule, graph coloring, Welsh – Powell algorithm

INTRODUCTION

Routine activities of every study program at Universitas Advent Indonesia before each semester begins are course scheduling. The scheduling process was still manual, which often cause some schedule clashing. As a result, lecture sessions are ineffective because the clashing courses have to be rescheduled until no clashing schedules are left.

In preparing the schedules, several components have to be considered, such as courses, lecturers, rooms, available schedule hours, and students who must repeat several courses or students who want to take additional courses. This process is quite complicated and time-consuming, especially if done manually.

To improve the quality of the academic services, finding a solution to these problems is necessary. One technique that can be used to overcome these problems is by using graph

coloring techniques (Munir, 2014). Graph coloring has many applications such as map coloring, task scheduling, parallel computation, network design, etc (Dandashi, 2010). In course scheduling, courses represent the vertices, and the connection between two courses such that both cannot be scheduled simultaneously represent the edge.

One of the graph coloring algorithms is the Welch-Powell algorithm (Munir, 2014). Welch-Powell algorithm performs coloring based on the highest vertices degree or Largest Degree Ordering (LDO) (Astuti, 2011). Although this algorithm does not always provide the minimum number of colors needed to color a graph, but it's practical enough.

In this study, Welch-Powell Algorithm was applied using C++ programming language to help the scheduling process in the Mathematics Department at Universitas Advent Indonesia for the even semester of the 2018/2019 academic year.

METHODS

The developed application program in this research applied FAST methodology consisting of six stages which were conducted sequentially. Below are the conducted procedures (Heriyanni, 2014):

1. Scope definition

This stage was started by collecting relevant information, then continued to formulating the problems and scope.

2. Problem analysis

At this stage, the problems were Identified and evaluated.

3. Requirement analysis

Collecting and analyzing the required data was carried out at this stage.

4. Decision analysis

Selection was performed on the development algorithm, as well as the hardware and software used to implement the algorithm.

5. Logical design

A logical design for the application program development was made at this stage.

6. Physical design and integration

The conducted activity in this stage was developing the application program used to implement the selected algorithm. After that, the application program was installed and used.

RESULTS

Scope Definition

1. Problems

To gather the information in the form of course scheduling problems faced by the Mathematics Education Department (MED), direct observations were conducted during the registration process at the beginning of the semester. Besides that, an interview session was made with the dean of MED to enrich the information gathered. According to the observation and interview results, some course scheduling problem faced by the MED are listed below:

- 1) The scheduling process was still manual. The dean has a hard time scheduling the courses, and the process requires a lot of time to complete.
- 2) There are still some clashing courses and need no be rescheduled during the registration period.

2. Scopes

The anticipated result was to boost the course scheduling process and avoid course clashing.

Problem Analysis

There were several weaknesses determined on the current course scheduling process. In addition to that, the solutions to overcome the weaknesses were also given. The table below shows the identification and the solution of the problems.

Table 1. The Identification And The Solution Of The Problems.

Problems	Time-consuming	No practical scheduling skill	Course clashing
Solutions	Automatic scheduling made by machines to reduce scheduling time.	Implement a graph coloring technique as a practical scheduling skill.	Graph coloring avoid coloring the same color for every two-vertex connected with an edge. In the other words no clashing courses will be scheduled at the same time.

Requirement Analysis

The required data for course scheduling were gathered from the Academic Administration Bureau (BAA). In addition to that, an interview with the dean of MED was made to identify the course scheduling limitations.

The data collected for this research was the even semester courses list for each batch in the Mathematics Education Department, credits (C) and course type (T) for each course, the instructor for each course, instructors which have been scheduled in the other departments, special case students, and fixed schedule. Schedules for general courses were already set by the BAA, and schedules for the senior courses (batch 2015) were set in the evening due to *Praktek Pengalaman Lapangan* sessions from the morning till afternoon. As for the *Skripsi II* course, it was scheduled on Friday at 1300 until 1600 which was out of the normal available schedule time because no class will be held for this course.

Table 2. Collected Data

No .	Course Code	Course Name	T	C	Instructor	Batch	Special Case	Fixed Schedule
1	MKU143	Bahasa Indonesia	G	2	Susri	2018		26, 27
2	ENG1206	Bahasa Inggris II	G	2	X	2018		10, 11
3	KIP1202	Falsafah Dasar-Dasar Kesehatan	M	2	Y	2018		12, 13
4	MAT1212	Fisika Dasar II	M	3	Andi	2018		
5	MAT1201	Geometrik Analitik	M	3	Nora	2018		
6	KIP1203	Kapita Selecta Matematika Sekolah Menengah Pertama	M	3	Nora	2018		
7	MKU1103	Pendidikan Kewarganegaraan	G	2	Z	2018		8, 9
8	KIP1201	Pendidikan Sosial dan Budaya	M	2	Mangadarr	2018		
9	MA152414	Aljabar Matriks	M	2	Sonya	2017		
10	MKU2201	Bahasa Inggris IV	G	2	A	2017		14, 15
11	MKU2202	Daniel dan	G	3	B	2017		8, 9, 24

		Wahyu						
12	MA15244 9	Fisika Listrik Magnet	M	3	Andi	2017		
13	MTK2202	Kalkulus Integral	M	3	Louise	2017	1522012	
14	MA15241 3	Kurikulum dan Pembelajaran	M	2	Kartini	2017	1522012	
15	MA15241 2	Profesi dan Pengelolaan Pendidikan	M	2	Kartini	2017		
16	MA15241 6	Statistika Dasar	M	3	Kartini	2017		
17	MA15362 4	Media Pembelajaran Matematika	M	3	Kartini	2016	1722009, MTK2017	
18	KIP3201	Metode Penelitian Matematika	M	2	Louise	2016	1522012, 1722009	
19	MTK3201	Porgram Linier	M	3	Sonya	2016		
20	MTK3202	Persamaan Diferensial Biasa	M	3	Andi	2016	1522012, 1722009	
21	MTK3203	Teori Bilangan	M	2	Louise	2016	1522012, 1722009	
22	KIP3203	Kajian Masalah Matematika	M	2	Sonya	2016	1722009	
23	MKK1234	Fisika Modern II	M	3	Horasdia	2016	1722009	32, 33, 34
24	A12	Transformasi Geometri	M	3	Sonya	2016		
25	ENG3210	Bahasa Inggris VI	G	2	C	2015	1722009, MTK2016	26, 27
26	MTK4201	Fungsi Variabel Kompleks	M	3	Nora	2015	MTK2016	
27	MTK4202	Metode Numerik	M	3	Andi	2015	MTK2016	
28	MTK4203	Analisis Real	M	3	Louise	2015		
29	KIP4201	Bimbingan Konseling	M	2	Mangada r	2015		
30	MTK4204	SKRIPSI II	M	3	Louise	2015		
31	B11		O	3	Andi	0		0, 1, 16
32	B12		O	3	Andi	0		2, 17, 18
33	B13		O	3	Nora	0		0, 1, 16
34	B14		O	3	Nora	0		2, 17, 18
35	B15		O	3	Kartini	0		0, 1, 16
36	B16		O	3	Kartini	0		32, 33, 34

The limitations for the scheduling process are as follows:

- 1) Every course which has three credit hours are divided into two sessions and for each session of the same course to be scheduled at the same day is minimalized. Each session of a course has to be assigned to the same room.
- 2) The available schedule time is from Monday to Thursday at 0800 until 1700 with rest at 1200, while on Friday from 0800 until 1100. This means that the total time slots are 18 slots with 17 two-hours slots and one one-hour slot.
- 3) There are three rooms provided for the MED main courses which are room 113, room 114, and room 115.

Decision Analysis

1. Development algorithm

The graph coloring algorithm used for the course scheduling was the Welch-Powell algorithm.

2. Hardware selection

The hardware used in this research was a laptop with the specification AMD A4-9125 Radeon R3 2.30 GHz processor, 4 GB RAM, and 500 GB hard disk

3. Software selection

The software chosen for the development of the application program was *CodeBlocks* to write C++ programming language, and *Microsoft Excel* to make the input file and read the output file.

Logical Design

The logical design for the application program development are as follows:

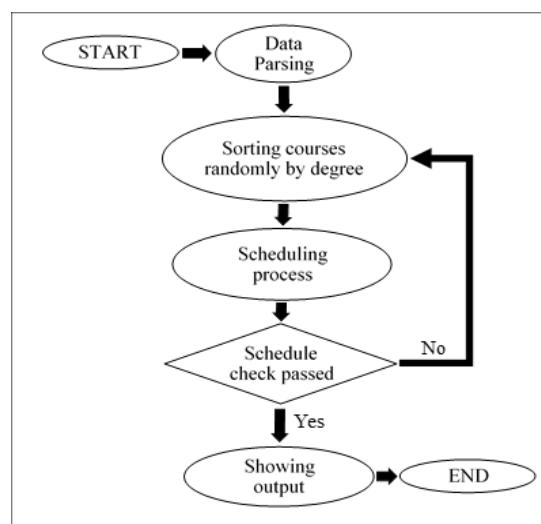


Figure 1. Welch-Powell algorithm scheduling procedures.

1. Data parsing

The data for all the courses which is the course code, course name, course type, instructors, credit hours, department, batch, special case students, and fixed schedule obtained from the interviews were put into the input (.csv) file with the help of *Microsoft Excel*. Then, each course data is put into a class and stored in a map.

	A	B	C	D	E	F	G	H	I
1	Course code	Course name	Type	Instructor	Credits	Department	Batch	Special case	Fixed schedule
2	MKU143	Bahasa Indonesia	U	Susri	2	MTK	2018		26 27
3	ENG1206	Bahasa Inggris II	U	X	2	MTK	2018		10 11
4	KIP1202	Falsafah Dasar-Dasar Kesehatan	M	Y	2	MTK	2018		12 13
5	MAT1212	Fisika Dasar II	M	Andi	3	MTK	2018		
6	MAT1201	Geometrik Analitik	M	Nora	3	MTK	2018		
7	KIP1203	Kapita Selecta Matematika Sekolah Menengah Pertama	M	Nora	3	MTK	2018		
8	MKU1103	Pendidikan Kewarganegaraan	U	Z	2	MTK	2018		8 9
9	KIP1201	Pendidikan Sosial dan Budaya	M	Mangadar	2	MTK	2018		
10	MA152414	Aljabar Matriks	M	Sonya	2	MTK	2017		
11	MKU2201	Bahasa Inggris IV	U	A	2	MTK	2017		14 15
12	MKU2202	Daniel dan Wahyu	U	B	3	MTK	2017		8 9 24
13	MA152449	Fisika Listrik Magnet	M	Andi	3	MTK	2017		
14	MTK2202	Kalkulus Integral	M	Louise	3	MTK	2017	1522012	
15	MA152413	Kurikulum dan Pembelajaran	M	Kartini	2	MTK	2017	1522012	
16	MA152412	Profesi dan Pengelolaan Pendidikan	M	Kartini	2	MTK	2017		
17	MA152416	Statistika Dasar	M	Kartini	3	MTK	2017		
18	MA153624	Media Pembelajaran Matematika	M	Kartini	3	MTK	2016	1722009 MTK2017	
19	KIP3201	Metode Penelitian Matematika	M	Louise	2	MTK	2016	1522012 1722009	
20	MTK3201	Porgram Linier	M	Sonya	3	MTK	2016		
21	MTK3202	Persamaan Diferensial Biasa	M	Andi	3	MTK	2016	1522012 1722009	
22	MTK3203	Teori Bilangan	M	Louise	2	MTK	2016	1522012 1722009	
23	KIP3203	Kajian Masalah Matematika	M	Sonya	2	MTK	2016	1722009	
24	MKK1234	Fisika Modern II	M	Horasdia	3	MTK	2016	1722009	32 33 34
25	A12	Transformasi Geometri	M	Sonya	3	MTK	2016		

Figure 2. Input file format.

2. Sorting courses randomly by degree

Degree calculation process was done to the parsed courses data. The degree of a course was determined by the number of other courses which has the same instructor or common student participants. After that, every course was sorted randomly by degree in descending order. The course was sorted randomly because there were some courses with the same degree. This will vary the courses arrangement for each sorting. Different courses arrangement means different output.

3. Scheduling

In the Welch-Powell algorithm, vector coloring and vector deletion is done. In scheduling, a vector represents a course. Two vectors are called adjacent to each other when the vector has the same instructor or student participants or allocated room. If two vectors are allocated to the same time slot, then the vectors are called related to each other. The room were allocated along with vector coloring process, and time slot were allocated during the initial vector coloring. The Welch-Powell algorithms procedure in course scheduling are as follows:

1) Initial vector coloring

Uncolored vector with the largest degree is colored with a new color, a compatible room were allocated to the vector, and a free time slot is allocated with the color. If the vector has a fixed schedule, the time slot corresponding to the fixed schedule is allocated with the color instead and all vectors related with the initial vector is colored with the same color.

2) Vector deletion

Vector deletion is done to all vectors which are adjacent with the previously colored vector (current color). If there are vectors with fixed schedule colored with the current initial vector color, then all the uncolored vectors with fixed schedule is deleted as well.

3) Next vector coloring

The remaining vector with the largest degree is colored with the same color as the initial vector and a compatible room is allocated to the vector if no room is allocated to the vector. If the vector has a fixed schedule and there are no deleted vectors related with the current vector then all the related vectors is colored with the same color, and the time slot corresponding to the fixed schedule, instead of the previously allocated time slot, is allocated with the current color.

4) Repetition

Step b) and step c) is repeated until all the remaining vector were colored or all rooms has been allocated.

5) New color

All the deleted vectors were restored and step a) until step d) is repeated until all vectors are colored.

4. Schedule check

If the total color is more than the total time slots, then the scheduling process is repeated from step 2.

5. Output

The scheduling results are displayed.

Physical Design and Integration

1. Physical design

Below is the display for the main page of the application program

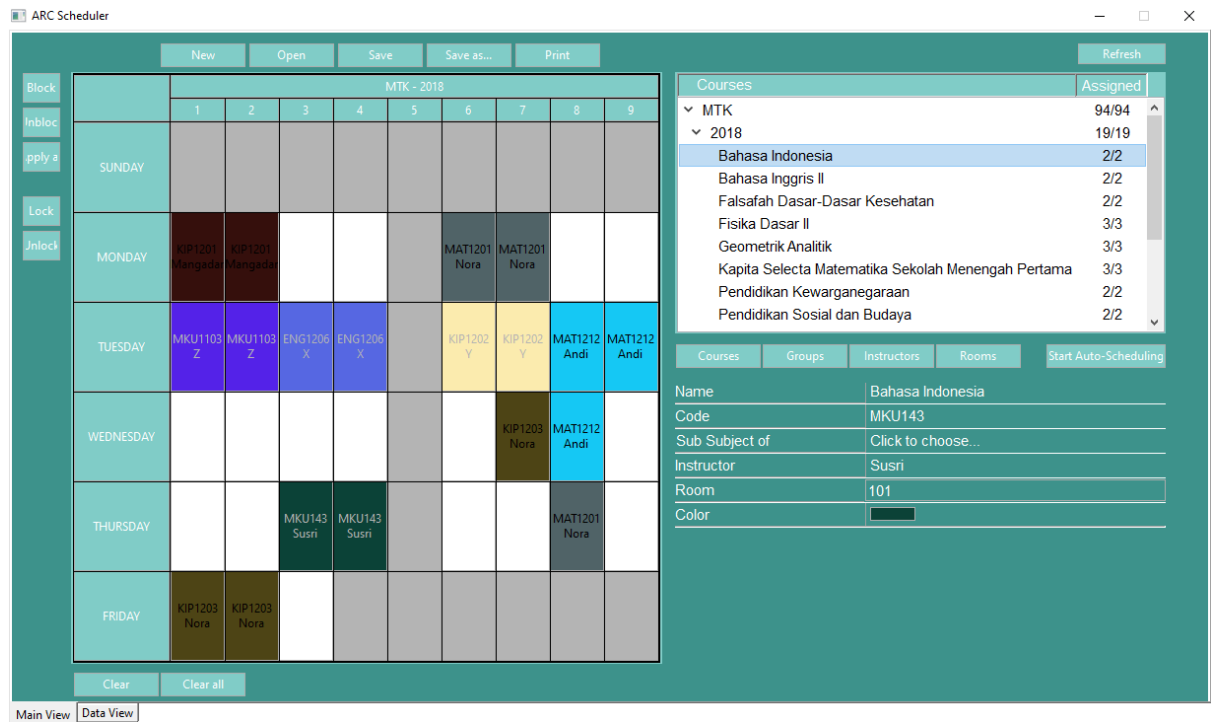


Figure 3. Main page display.

The main page has the following components:

- 1) New, Save, Save As, and Print menus to manage workings.
- 2) Block, Unblock, Lock, Unlock menus to manage the available schedule hours as well as the fixed course schedule.
- 3) Courses, Groups, Instructors, and Rooms menus to view the courses, groups, instructors, and rooms data respectively.
- 4) Start Auto-Scheduling menu to start the course scheduling process.
- 5) Refresh menu to refresh the components and data.
- 6) Timetable to view and manage the allocated courses.
- 7) Details of the selected items are shown at the bottom right part.

Below are the display for the data view page of the application program

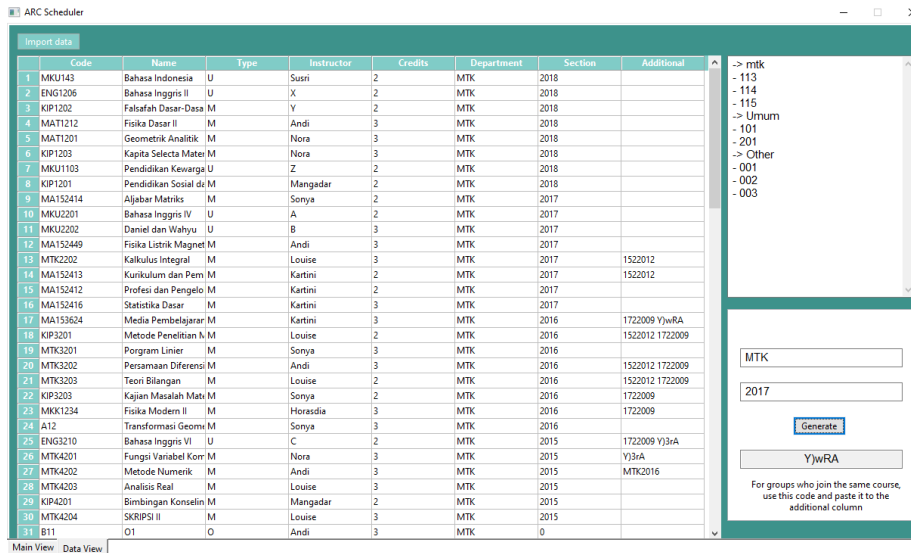


Figure 4. Data view page.

The data view page has the following components:

- 1) Import menu to import the input (.csv) data file.
- 2) Data table to view or edit the input data.
- 3) Text editor at the top right position to edit the rooms data.
- 4) A window at the bottom right position to generate the code for a group by clicking the Generate button.

The output (.mht) design viewed by *Microsoft Excel* is shown below. This output file can be accessed by clicking the Print menu in the main page.

Jadwal Mata Kuliah MTK Angkatan 2015					Jadwal Mata Kuliah MTK Angkatan 2016										
TIME	DAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TIME	DAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0800-0900								0800-0900			Metode Penelitian Matematika (Louise) [114]	Transformasi Geometri (Sonya) [113]			
0900-1000								0900-1000				Transformasi Geometri (Sonya) [113]			Fisika Modern II (Horasdia) [113]
1000-1100						Bahasa Inggris VI (C) [201]		1000-1100			Kajian Masalah Matematika (Sonya) [115]				
1100-1200								1100-1200			Persamaan Diferensial Biasa (Andi) [113]	Pogram Linier (Sonya) [115]			
1200-1300								1200-1300							
1300-1400								1300-1400			Pogram Linier (Sonya) [115]	Persamaan Diferensial Biasa (Andi) [113]			
1400-1500			Analisis Real (Louise) [114]	Metode Numerik (Andi) [113]	Fungsi Variabel Kompleks (Nora) [113]		SKRIPSI II (Louise) [113]	1400-1500			Pogram Linier (Sonya) [115]	Persamaan Diferensial Biasa (Andi) [113]	Media Pembelajaran Matematika (Kartini) [114]		
1500-1600		Analisis Real (Louise) [114]	Bimbingan Konseling (Mangadar) [113]	Fungsi Variabel Kompleks (Nora) [113]	Metode Numerik (Andi) [113]			1500-1600				Teori Bilangan (Louise) [113]		Media Pembelajaran Matematika (Kartini) [114]	
1600-1700								1600-1700							

Figure 5. Batch 2015 and batch 2016 schedules.

Jadwal Mata Kuliah MTK Angkatan 2017					Jadwal Mata Kuliah MTK Angkatan 2018										
TIME	DAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TIME	DAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
0800-0900				Daniel dan Wahyu (B) [201]		Daniel dan Wahyu (B) [201]	Kalkulus Integral (Louise) [114]	0800-0900				Pendidikan Kewarganegaraan (Z) [101]			Geometrik Analitik (Nora) [115]
0900-1000				Daniel dan Wahyu (B) [201]				0900-1000							
1000-1100				Kurikulum dan Pembelajaran (Kartini) [113]		Profesi dan Pengelolaan Pendidikan (Kartini) [115]		1000-1100				Bahasa Inggris II (X) [101]		Bahasa Indonesia (Susri) [101]	
1100-1200					Statistika Dasar (Kartini) [115]			1100-1200					Fisika Dasar II (Andi) [113]		
1200-1300								1200-1300							
1300-1400			Statistika Dasar (Kartini) [115]		Kalkulus Integral (Louise) [114]			1300-1400			Kapita Selecta Matematika Sekolah Menengah Pertama (Nora) [114]	Falsafah Dasar-Dasar Kesehatan (Y) [113]			
1400-1500						Fisika Listrik Magnet (Andi) [114]		1400-1500					Geometrik Analitik (Nora) [115]		
1500-1600		Aljabar Matris (Sonya) [114]	Bahasa Inggris IV (A) [101]	Fisika Listrik Magnet (Andi) [114]				1500-1600			Fisika Dasar II (Andi) [113]		Pendidikan Sosial dan Budaya (Mangadar) [115]	Kapita Selecta Matematika Sekolah	
1600-1700								1600-1700							

Figure 6. Batch 2017 and batch 2018 schedules.

2. Integration

After several tests, when the application program was ready, it was integrated into the course scheduling process in the MED. The performance test results of the application program are as follows:

Table 3. The performance test results of the application program

Test No.	Iterations	Execution (seconds)	time
1	10	0.718	
2	10	0.625	
3	6	0.359	
4	3	0.235	
5	9	0.516	

DISCUSSION

The application of graph coloring helps course scheduling. Graph coloring provide a quick and accurate solution for setting up course schedules.

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