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A Comparison of Welch Powell Algorithm and Greedy Algorithm in Odd Semester Lecture Room Scheduling Optimization Faculty of Computer Science

Alif Nur Fadilah[1], Pungkas Subarkah[1*], Reyvaldo Shiva Pramudya[1], Amin Syabani[1]
[1]Department of Informatics, Amikom Purwokerto University, Indonesia
22sa11a08@mhs.amikompurwokerto.ac.id

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ABSTRACT

Scheduling is a systematic method to optimize work time, and avoid failure when problems occur. Scheduling is widely applied in the world of education, one of which is in preparing course schedules. Scheduling itself needs to be optimized to ensure a smooth lecture process without any problems between courses. As happened at the Faculty of Computer Science, Amikom Purwokerto University, where in the preparation of the schedule there is no information about lecture rooms. Therefore, the author compiled a lecture hall scheduling optimization journal by comparing the performance between the Welch Powell Algorithm and the Greedy Algorithm as optimization and graph coloring on the lecture hall schedule.The data used in this study are 88 courses spread across 3 study programs, namely Informatics Study Program, Information Systems Study Program, and Informatics Engineering Study Program. This research uses a comparative method on graph vertex coloring, where execution time as duration, lines as algorithm complexity, and manual algorithm calculation as parameters. Based on the research that has been done, the results of 14 full spectrum colors are obtained which are then applied to 23 lecture rooms that can be used without clashes at the Faculty of Computer Science. This can minimize the possibility of overlapping room usage between courses. In addition to comparing the performance of the Welch-Powell Algorithm and the Greedy Algorithm to produce optimal scheduling of lecture rooms, this research can also optimize the schedule of lecturers when entering class to optimize students to be more organized in entering lecture classes at the Faculty of Computer Science, Amikom Purwokerto University.

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A. INTRODUCTION

Course scheduling of an educational institution is the determination of a certain period of time for courses offered by the educational institution during a certain semester (Kehinde et al., 2024). The purpose of scheduling is to optimize work time, reduce workload, and avoid constraints and human error. In the world of education, scheduling is usually used to create study/lecture schedules, quiz schedules, semester exam schedules, final exams, teacher syllabi, and others that need to be made every semester. The main elements required when designing a course schedule are courses, lecturers, students, time, and classrooms. Setting a timetable is not an easy task, and planners often face several constraints. Scheduling constraints are classified into two types: hard constraints and soft constraints. Hard constraints are absolute rules set by the university (Musa & Oyelakin, 2024), such as lecturers or instructors cannot be in more than one location at the same time, and the necessary resources must be provided within one teaching period. Meanwhile, The soft constraints reflect the wishes of the parties involved that can be ignored without serious effect (Musa & Oyelakin, 2024).

To solve common scheduling problems, scheduling optimization is required. One branch of mathematics that is commonly used to solve Design Optimization problems is graph theory. Graph are one of the most commonly studied topics in graph theory , popularized by a Swiss mathematician in 1736 named Leonhard Euler who discovered the secret of the Königsberg Bridge (Pamela, 2023).The general definition of graph theory involves the use of primitive relations, which are variables that revolve around a set of vertices and edge relations (Chalopin et al., 2024). Using graph theory , researchers can test matrix hypotheses that map the relationship between one vertex and another defined by directed edges, regardless of whether the vertices are connected by the same edge (Leong et al., 2024). In complex systems, graph theory provides various tools to measure and analyze connectivity patterns (Phillips et al., 2015). The application of graph theory is also widely used to solve planning problems, as has been done by several researchers, including research with the title "Graph Coloring based Scheduling Algorithm to automatically generate College Course Timetable". The author uses graph theory and graph vertex coloring method to automatically generate lecture schedules in this research (Nandal et al., 2021).

In addition to the research described above, picket planning at one of the junior high schools in Kemranjen also applies the Welch-Powell algorithm to graph coloring(Ermanto & Riti, 2022), Application of welch powell algorithm to identify class schedule conflicts at one of the informatics management colleges in Purwokerto (Fransisca & Kurniawan, 2020), Scheduling lectures at the Malikussaleh University Informatics Engineering Study Program (Abdullah et al., 2019), Preparation of Lecture Schedule in Mathematics Education Study Program Universitas Negeri Manado (Kawatu et al., 2023), and Lecture Scheduling in the Mathematics Study Program Faculty of Science and Technology State Islamic University of North Sumatra (Cipta et al., 2023).

Besides the Welch-Powell algorithm, graph theory can be applied to various other algorithms and techniques. This research with the title "A Hybrid Exam Scheduling Technique based on Graph Coloring and Genetic Algorithms Targeted Towards Student Comfort" uses existing genetic algorithms and applies them to graph coloring (Hassan et al., 2019). Further research that does not apply the Welch Powell algorithm is research on graph coloring in scheduling undergraduate mathematics courses at one of the universities in Sumedang using the Greedy algorithm. Just like the Welch-Powell algorithm, the greedy algorithm is used to solve everyday optimization problems. Greedy algorithms allow researchers to solve computational problems more efficiently than other optimization algorithms (Xiao et al., 2020). The algorithm is heuristic in nature, where the logical sequence is systematically organized based on problem-solving steps (Popov et al., 2020). Greedy algorithms are usually used to determine the best choice in a given problem situation. In general, this algorithm works by first sorting the degree of each vertex, then adding one new vertex at each stage (Shao et al., 2019). The addition of each new vertex is done by taking the vertex with the minimum degree contained in the graph (Chen & Lv, 2022). This algorithm is also widely used to solve every problem due to its intuitive strategy and relatively high performance efficiency (Lu et al., 2021).

The next research that does not use the Welch Powell algorithm is research entitled "Optimizing the Implementation of the Greedy Algorithm to Achieve Efficiency in Garbage Transportation Routes" (Hidayatulloh et al., 2023), "SAGAS: Simulated annealing and greedy algorithm scheduler for laboratory automation" (Arai et al., 2023), "Shortest Fuzzy Cycle on Transportation Network Using Minimum Vertex Degree and Time-dependent Dijkstra's Algorithm" (Çakir et al., 2021), "Dijkstra's algorithm to find the nearest vaccine location" (Jason et al., 2022), "A greedy algorithm for wavelet-based time domain response spectrum matching" (Nie et al., 2023), and the application of the Recursive Largest First Algorithm to the Employee Work Shift Scheduling Application at PT. Invilon Sagita Medan (Buulolo & Simanjorang, 2020).

In previous research, it has been explained that scheduling problems occur a lot in everyday life, especially in the field of education. This scheduling problem is also experienced by the faculty of Computer Science, Amikom University Purwokerto. Due to limited space and teaching time, some courses overlap with each other. In addition, the decrease in COVID-19 infection rates also opens up greater opportunities for face-to-face learning, where all study programs carry out the learning process simultaneously. To overcome these problems, the author focuses this research on optimizing the lecture hall schedule in odd semesters at the Faculty of Computer Science, Amikom University Purwokerto. This scheduling is done by comparing the time efficiency and accuracy level of manual testing with Welch-Powell algorithm and Greedy Algorithm. This can minimize the possibility of overlapping room usage between courses. In addition to comparing the performance of the Welch-Powell Algorithm and the Greedy Algorithm to produce optimal lecture room scheduling, this research can also optimize the lecturer's schedule when entering the classroom optimize students to be more organized in entering lecture classes at the Faculty of Computer Science, Amikom Purwokerto University.

B. METHODS

This research is an applied research that applies graph node coloring. The subject of this research is data collection from the college's Academic Administration Bureau consisting of 88 courses in 3 study programs of the Faculty of Computer Science, namely Informatics Engineering, Information Systems, and Information Technology where the data sampled are odd semester courses consisting of semesters I, III, V, and VII, while the rooms available and used to conduct the lecture process consist of 23 rooms, including R.2.1, R.2.2.1, R.2.2.1, R.2.2, R.2.3, R.2.2.1. .1, R.2.2.1, R.2.2.2 .1, R.2.2, R.2.3, R.2.4, R.3.1, R.3.2, R.3.3, R.3.4, R.3.5, R.3.6, R.3.7, R.3.8, R.3.9, R.4.1, R.4.2, R.4.3, R.4.4, Lab.1, Lab.2, Lab.3, Lab.4, Lab.5, and Lab.6, as shown in Figure 1, Figure 2 and Figure 3.

Figure 1, below is the odd semester course schedule for the information systems study program.

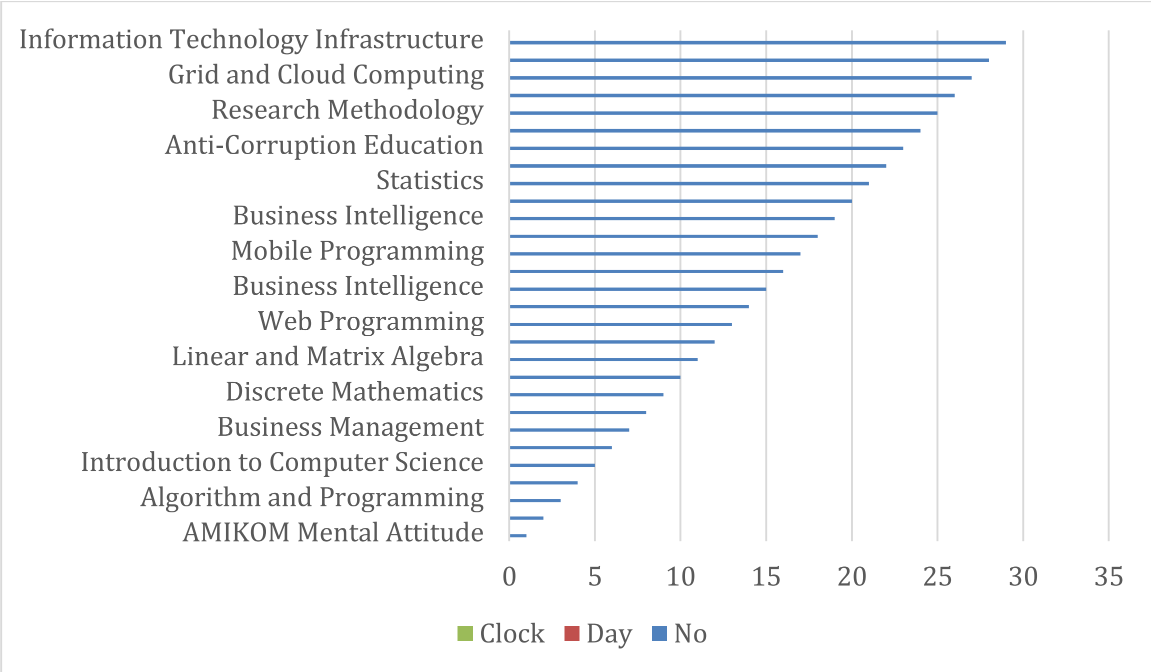

Figure 1. Schedule Information System

Figure 2, below is the odd semester course schedule for the informatics study program.

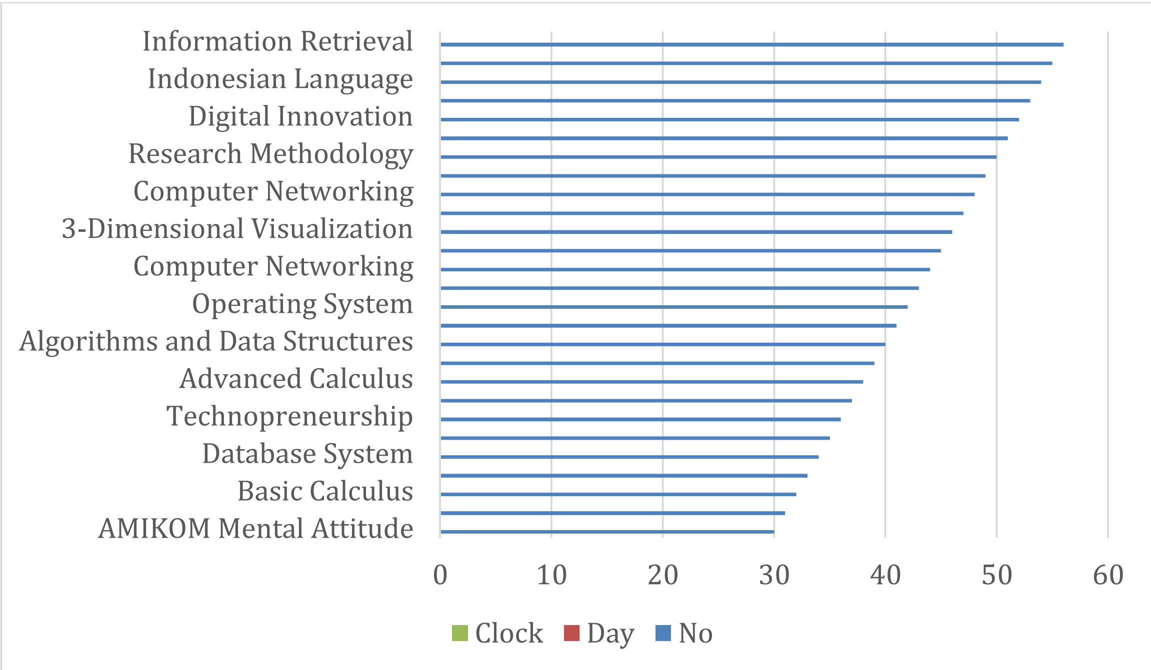

Figure 2. Schedule Informatics

Figure 3, below is the odd semester course schedule for the information technology study program.

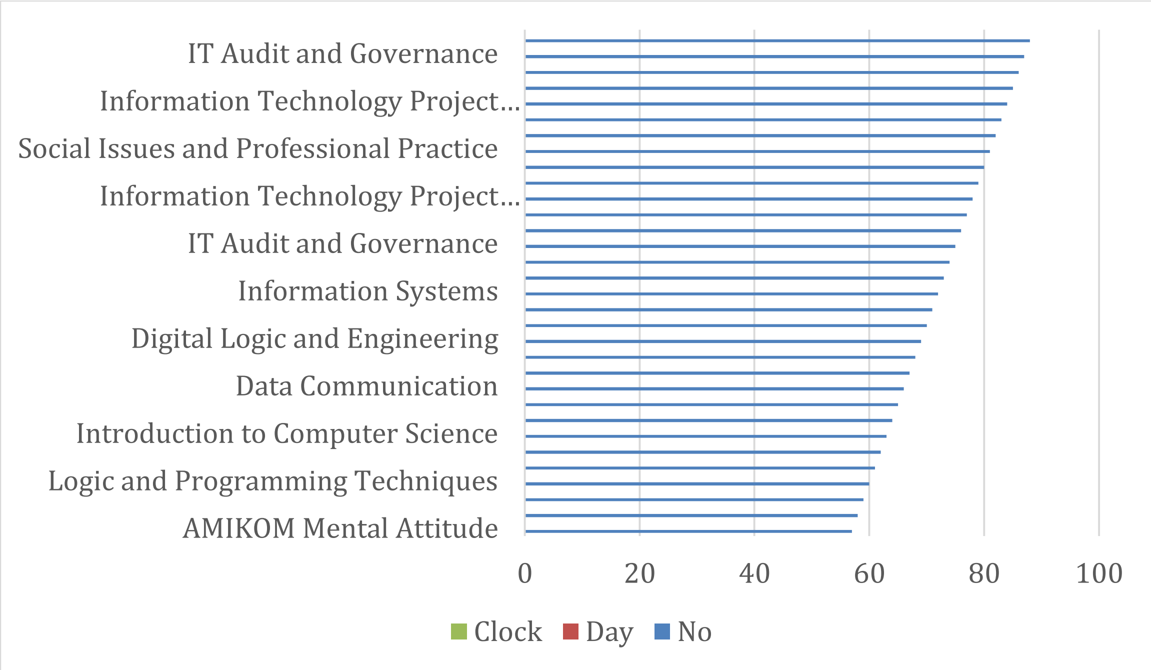

Figure 3. Schedule Information Technology

Based on observations from the data the author has, there is no information about the rooms used for lectures . Therefore , the preparation of the schedule for using lecture rooms must be optimized to avoid constraints and overlaps between one course or study program and another study program. Before implementing the graph into the algorithm, the authors organize the research design flow Figure 4.

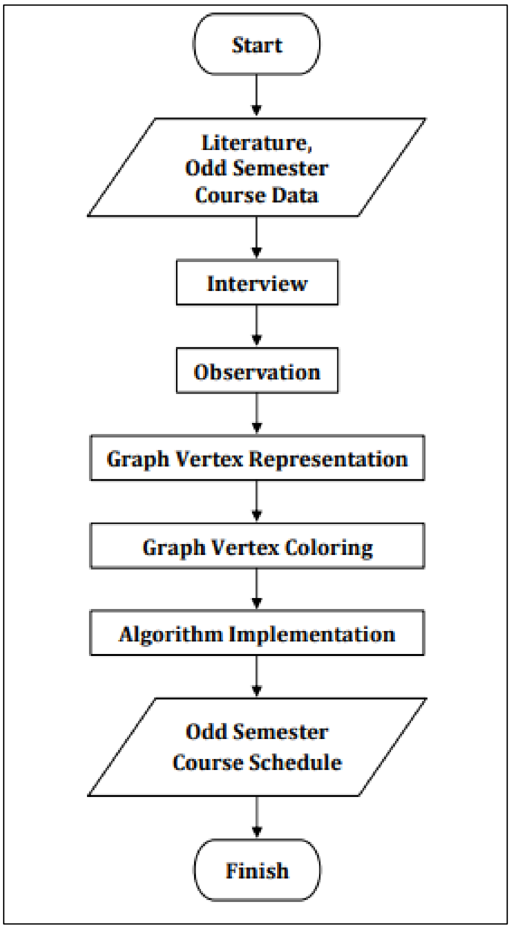

Figure 4. Research Flow

The first step in this research process is to review literature from various sources, including books, journals, and other sources. After conducting a literature study, the next step is to collect course data from each study program of the Faculty of Computer Science, Amikom University Purwokerto. The Faculty of Computer Science has three study programs, namely Information Systems, Informatics, Information Technology. Course data in each of these study programs will be observed first by the author to obtain which courses overlap. Next, graph node coloring is performed on the representation result and applied to the algorithm. Graph vertex coloring is a method of labeling each vertex in a graph, so that there is no possibility of two neighboring vertices having the same color (Xu et al., 2018). In this case, the algorithms used by the author are Welch Powell algorithm and Greedy algorithm. Furthermore, in the preparation of the odd semester course schedule, namely by using the coloring results and the application of the two most efficient algorithms in the graph. Before preparing the odd semester course schedule using the coloring results and application of the two algorithms, the following is a depiction of the steps of applying the Welch Powell algorithm in the form of a flow chart in Figure 5.

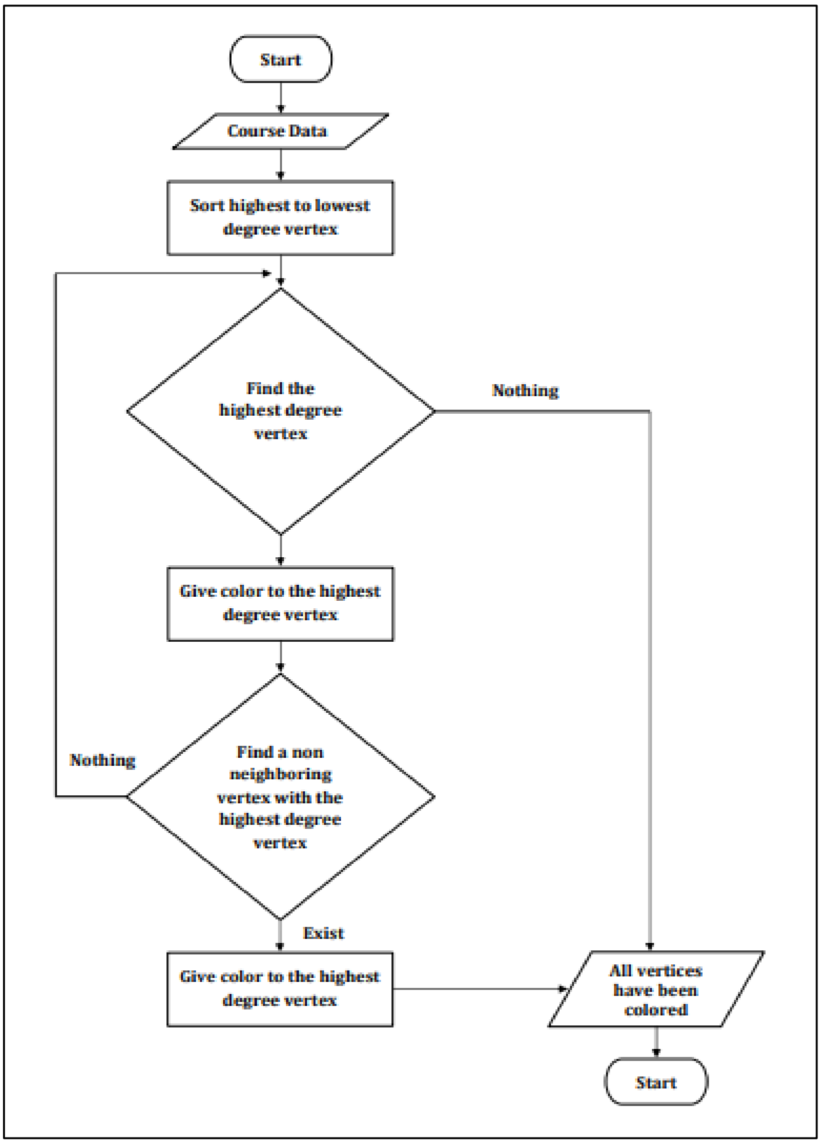

Figure 5. Welch Powell Algorithm Flowchart

The description of the steps of applying the Welch Powell Algorithm described in the form of the flowchart above is as follows:

1. Find one vertex with the highest degree
2. Give a new color to the vertex with the highest degree, followed by other vertices that are not neighboring with the vertex with the highest degree
3. Gives a new color to the highest degree vertex next
4. Repeats the vertex coloring until the end

While the implementation steps of the Greedy algorithm are as follows:

1. Sort the vertices in the graph from the highest degree to the lowest degree.
2. Determine the order of colors to be used (e.g. {1,2,3, . . ., n}).
3. Select the first vertex with the highest degree and give it color 1.
4. Select the vertex with the next highest degree and assign the color in the next order that has not been assigned to other vertices that are neighbors of the first vertex
5. Repeat the fourth step until all vertices are colored.

The method used in this research is the comparison method between two algorithms, or the comparison method. The parameters used to test the course schedule are time efficiency, algorithm complexity, and manual testing of Welch-Powell algorithm and Greedy Algorithm.

1. The time efficiency parameter is used to calculate the algorithm execution process. The less time it takes, the more efficient the algorithm used to compile the scheduling.
2. The algorithm complexity parameter works by comparing the number of program lines applied and the number of steps that must be executed in an algorithm.
3. While manual testing is carried out to determine the level of truth of the test results until no constraints are found on the course schedule.

In this research, the main components chosen by the author to compile the odd semester scheduling of the Faculty of Computer Science, Amikom University Purwokerto are the courses and lecture days and hours where courses are represented as nodes, while lecture days and hours are represented as nodes. as nodes, while lecture days and hours are represented as edges. This is done because reviewing the number of courses that must be taken at Amikom Purwokerto University is quite a lot with limited number of rooms, as shown in Figure 6.

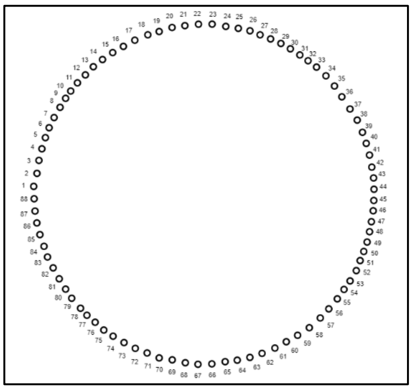

Figure 6. Vertex Representation

From Figure 6, the course data that has been obtained is then represented in graph form as a node distribution.

C. RESULT AND DISCUSSION

The programming languages applied in this research are C+ programming language with device requirements, namely:

1. Hardware : Acer Aspire 3 laptop, Processor AMD A-4, and RAM 4Gb
2. Software : Dev C++

This research was conducted by comparing the best performance between the two algorithms, namely the Welch Powell algorithm and the Greedy algorithm. Before representing the edges and vertices into graph form, the author first determines the adjacency matrix between one vertex and another vertex as shown in Table 1, Table 2, Table 3, Table 4, Table 5, and Table 6.

Table 1. Adjacency Matrix Course 1

Course	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Degree	0	6	7	5	7	6	3	4	7	7	8	4	7	5	7

Table 2. Adjacency Matrix Course 2

Course	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Degree	10	6	0	1	7	5	7	7	5	4	8	5	7	5	0

Table 3. Adjacency Matrix Course 3

Course	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Degree	7	7	6	4	7	7	4	4	11	7	6	4	7	7	4

Table 4. Adjacency Matrix Course 4

Course	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Degree	13	7	7	10	6	5	4	9	6	5	3	0	12	7	5

Table 5. Adjacency Matrix Course 5

Course	61	62	63	64	65	66	67	68	69	70	71	72	73	54	75
Degree	7	4	5	4	6	7	1	6	8	10	6	3	4	11	7

Table 6. Adjacency Matrix Course 6

Course	76	77	78	79	80	81	82	83	84	85	86	87	88
Degree	7	7	6	4	4	7	5	4	5	7	7	7	4

From Table 4, Table 5, Table 6, Table 7, Table 8, and Table 9 are the results of determining the adjacency matrix of the course schedule of the Faculty of Computer Science, Amikom Purwokerto University by searching for the highest degree node value in a graph where the rows and columns in the matrix state the distribution of courses, the results show that the highest degree of the Faculty of Engineering course adjacency matrix is at a value of 13 (thirteen) and the lowest degree is at a value of 0 (zero). After that, it is represented in the form of a graph as shown in Figure 7.

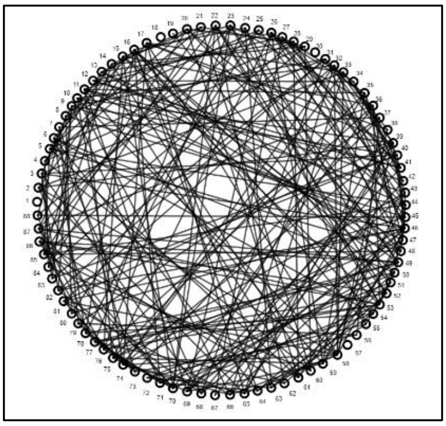

Figure 7. Side Vertex Representation

Figure 7 is a representation of the subject in the form of a graph which will then be given coloring to each vertex. The representation of graph node coloring using the Welch Powell Algorithm can be seen in Figure 8.

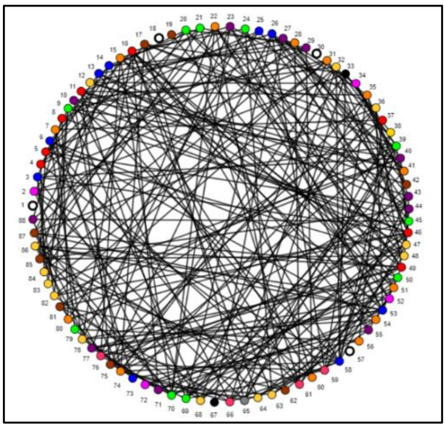

Figure 8. Welch Powell graph coloring

The graph vertex coloring process using Welch Powell algorithm begins with,

1. Determine the highest degree vertex to lowest degree
2. Take one of the LDO (Largest Degree Ordering), then give coloring to that vertex and on other vertices that do not neighbor it
3. Next, select the second LDO, then give the next next coloring that is different from the first LDO and give the same coloring to the the second LDO
4. Repeat the third step until all vertices are colored

Based on the use of the Welch Powell Algorithm in coloring the graph vertices above, the result shows that the subject color is divided into 14 colors, namely red, blue, green, orange, purple, yellow, magenta, brown, black, gray, gold, navy, turquoise, and maroon. Graph vertex coloring in the Greedy algorithm is not much different from the Welch-Powell algorithm. Graph vertex coloring using the greedy algorithm is done as follows.

1. Select one LDO (vertex with the highest degree) and assign a color to it.
2. Select the second LDO and give it a different color from the first vertex.
3. Repeat the coloring step until all vertices are colored.

If in Welch Powell's algorithm, the coloring of graph vertices is done based on the first LDO (Largest Degree Ordering) and followed by giving the same color to vertices that do not neighbor the first LDO, then in Greedy's algorithm, the graph coloring process is done according to its order, starting from the first LDO, second LDO, third LDO, to the last LDO. In this case, the concept of stages in the Greedy algorithm is heuristic. The graph coloring process in the Greedy algorithm is done based on the first LDO. In the compiled scheduling graph, the highest degree in the graph is 13 and 12, where the graph of 13 is vertex 46, then the graph of 12 is vertex 58.

1. The first LDO is vertex 46 which is then colored red.
2. The next coloring process is given to the LDO in the 12-valued graph which is vertex 58. Since vertex 58 is neighbor to vertex 46, vertex 58 is given a different color, which is blue.
3. Next, repeat the second step until all vertices of the same degree are colored.
4. When all vertices of the same degree have been colored, the next process is to color the vertices of the highest degree after 13 and 12.
5. In this case, the vertex with the next highest degree is vertex 39 with a total degree of 11. Since vertex 39 neighbors vertices 46 and 58, it should not be given the same color as LDO.
6. The coloring process continues until all vertices in the graph are colored As in Figure 9.

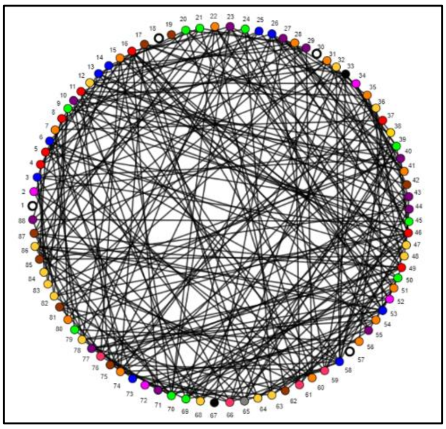

Figure 9. Greedy algorithm coloring result

Figure 9 is the result of the Greedy algorithm coloring flow which is not much different from the Welch Powell algorithm, the resulting graph coloring is also the same, where 14 colors are obtained. Based on the program testing process that has been carried out, it is known that the Welch Powell algorithm and the Greedy algorithm produce the number of values with the same vertices and coloring. The things that distinguish these two algorithms are described in Table 7 below.

Table 7. Testing Results

Algorithm	**Tester Parameters**				**Algorithm Complexity**
	Execution Time				
	Experiment 1 (Second)	**Experiment 2 (Second)**	**Experiment 3 (Second)**	**Average (Second)**	
Welch Powell	1145	1200	800.3	1087.2	127 Lines
Greedy	0.002	0.002	0.00005	0.000595557	33 Lines

The program testing process was carried out 3 times to obtain the maximum average value in the application of the algorithm. The execution process of the Welch Powell algorithm and the Greedy algorithm which is done manually and with the program, obtains the same results where the resulting number is as many as 14 (fourteen) colors. Based on the test results of both algorithms, it can be seen that the program execution time in the Greedy algorithm is faster than the Welch Powell algorithm. This happens because in the Welch Powell algorithm, data input is done after the program runs, so it takes relatively longer. Not only in terms of time, in terms of program complexity, the Greedy algorithm is superior to the Welch Powell algorithm where the Greedy algorithm consists of 33 program lines and the Welch Powell algorithm consists of 127 program lines. However, the program from Welch Powell's algorithm itself can produce more detailed output regarding the degree of each vertex, vertex adjacency, and color code information that functions as a chromatic number. Of the 14 colors that have been generated from testing these two algorithms will be represented into the use of classrooms Faculty of Computer Science, Amikom Purwokerto University which can be seen in Table 8.

Table 8. Classroom acquisition results with both algorithms

Color	Classroom
Red	R.2.1
Blue	R.2.2
Green	R.2.3
Orange	R.2.4
Purple	R.3.1
Yellow	R.3.2
Magenta	R.3.3
Brown	R.3.4
Black	R.3.5
Gray	R.3.6
Gold	R.3.7
Navy	R.4.1
Turqoise	R.4.2
Maroon	R.4.3

D. CONCLUSION AND SUGGESTIONS

Based on the research that we have done, it can be concluded that the Welch Powell algorithm and the Greedy algorithm have workflows that are not much different, but can get the same results, namely 14 (fourteen) colors are obtained which are then applied to the scheduling of rooms that will be used in the lecture process at the Faculty of Computer Science, Amikom Purwokerto University. In manual calculations, the Greedy algorithm has a slightly longer workflow due to the heuristic nature of the work where each node must be colored one by one based on the highest degree node.

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