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Examination Scheduling Algorithm Using Graph Colouring: A Case Study of the Departments Information Technology & Cybersecurity, Federal University of Technology, Akure, Nigeria

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ABSTRACT

Examination scheduling in academic institutions represents a complex optimization problem that requires efficient allocation of time slots and venues while minimizing conflicts. This study presents an automated examination scheduling system utilizing graph colouring algorithms to address scheduling challenges in Nigerian universities. A case study of 300-level students in the Cybersecurity and Information Technology departments at the Federal University of Technology, Akure (FUTA) was conducted. The research employed the DSATUR (Degree of Saturation) algorithm to model courses as vertices and student overlaps as edges in an undirected conflict graph. The system was implemented using Python programming language with NetworkX and Matplotlib libraries for graph manipulation and visualization. Results demonstrated successful conflict-free scheduling with optimal time slot allocation, reducing examination periods while satisfying both hard and soft constraints. The automated system generated efficient timetables in approximately 0.67 seconds, eliminating manual scheduling errors and significantly reducing administrative workload. This contribution offers Nigerian educational institutions a scalable and user-friendly solution for examination timetabling, adaptable to varying institutional requirements.

Keywords: Examination Scheduling, Graph Colouring, DSATUR Algorithm, Conflict Resolution, Python, Automated Timetabling, FUTA

1. BACKGROUND OF STUDY

Examination scheduling remains one of the most demanding administrative tasks in academic institutions worldwide. Universities must coordinate dates, times, courses, venues, and large student populations while satisfying both hard and soft constraints to avoid clashes and resource conflicts. In Nigerian universities where student enrolment continues to grow and academic programmes diversify; manual scheduling approaches have become increasingly inadequate. These traditional methods often lead to examination clashes, venue shortages, inconsistent allocation, and significant administrative inefficiencies.

Optimal examination scheduling aims to assign examinations to time slots in a manner that minimizes conflicts and resource violations. As noted by Oke et al. (2023), conventional manual techniques struggle to cope with the rising complexity of academic programmes, necessitating the adoption of computational optimization methods. One such method is graph colouring, a graph-theoretic approach in which vertices represent examinations and edges represent conflicts arising when two exams share at least one student. The objective is to assign the minimum number of colours (time slots) such that no two adjacent vertices share the same colour, thereby ensuring conflict-free scheduling (Biswas et al., 2023).

Graph colouring has emerged as a powerful technique for university timetabling due to its efficiency in minimizing resource use such as venues and invigilators while producing near-optimal schedules. Because the examination timetabling problem (ETP) is NP-complete, heuristic and metaheuristic approaches are frequently applied to obtain high-quality solutions within realistic computational timeframes. The Federal University of Technology, Akure (FUTA), like many Nigerian institutions, experiences recurring challenges in generating examination timetables manually. These challenges include error-prone processes, double allocations, delays, and difficulty adapting to last-minute changes or conflict adjustments. Such persistent issues highlight the need for an automated system capable of producing conflict-free, efficient, and adaptable examination timetables.

Previous studies have demonstrated progress but still present notable limitations. Sunday et al. (2024) developed an examination timetabling system using a hybridized Genetic Algorithm and Greedy Algorithm. Their model focused primarily on eliminating examination clashes within a single department. The approach optimized the assignment of exams to time slots by combining the exploratory power of evolutionary algorithms with the speed of greedy heuristics. Although effective in reducing conflicts, the system was tested on a limited dataset and placed strong emphasis on conflict minimization over other constraints such as venue utilization, fairness, or broader institutional requirements. Osama et al. (2019) proposed a hybrid examination scheduling technique that integrates graph colouring with Genetic Algorithms, with particular emphasis on improving student comfort.

Their method models exam conflicts using graph colouring while employing a Genetic Algorithm to refine the timetable and reduce student stress factors such as closely scheduled exams. The system demonstrates good performance in comfort-based scheduling but was validated on a relatively small dataset and focuses mainly on student-centered constraints rather than multi-objective optimization involving resources and administrative priorities. To address these gaps, this study proposes a graph-colouring-based examination scheduling system that is scalable for use in Nigerian universities. The system incorporates dynamic constraint handling, scalability, low computational complexity, multi-objective optimization, and strict validation procedures. It also features a user-friendly interface and real-time operation to promote practical usability and efficiency in academic environments.

2. GRAPH CONSTRUCTION AND COLOURING ALGORITHM

To solve the examination scheduling problem, a graph-theoretic approach was adopted. The mathematical formulation represents courses as vertices and conflicts as edges in an undirected graph G = (V, E), where:

$V = \{v_1, v_2, v_3, \ldots, v_n\}$ .... (1)

In equation 1, V represents the set of all courses to be scheduled, and n is the total number of courses. An edge $e \in E$ exists between two vertices v_i and v_j if and only if courses i and j have at least one student in common:

$e_{ij} \in E \leftrightarrow S_i \cap S_j \neq \emptyset$ .... (2)

Where S_i and S_j represent the sets of students enrolled in courses i and j respectively. The conflict graph attributes were represented by the adjacency matrix A and expressed as:

$A = [a_{ij}]$, where $a_{ij} = 1$ if $e_{ij} \in E$, otherwise 0 .... (3)

Where a_{ij} represents the presence (1) or absence (0) of conflict between courses i and j. The chromatic number $\chi(G)$ represents the minimum number of colors (time slots) required to color the graph such that no adjacent vertices share the same color. The DSATUR algorithm assigns colors based on saturation degree. The saturation degree sat(v) of a vertex v is defined as:

$sat(v) = | \{c : c \text{ is assigned to a neighbor of } v\}$ ....(4)

The algorithm selects the vertex with the highest saturation degree at each step, breaking ties by choosing the vertex with the highest degree. This strategy has been proven to produce near-optimal colourings for dense graphs typical in examination scheduling scenarios

3. DATA PRESENTATION

Data were collected from the Cybersecurity and Information Technology departments at FUTA for 300-level students. The timetable data were entered into Excel sheets and imported into Python using the Pandas library. The data were coded with serial numbers to prevent missing information from the dataset. Analysis was carried out using graph-theoretic algorithms implemented in NetworkX, with visualization performed using Matplotlib.

Table 1: Socio-Academic Characteristics of the Departments

DEPARTMENT	NO OF STUDENTS	NUMBER OF COURSES (1ST SEM)	NUMBER OF COURSES (2ND SEM)	TOTAL CREDIT UNITS
Cybersecurity	80	9	9	43
Information Technology	73	10	9	41
Total	**153**	**19**	**18**	**84**

Source: Fieldwork (2025)

The table above shows the distribution of students and courses across both departments. The data reveal that Information Technology has slightly more courses in the first semester but fewer total credit units compared to Cybersecurity.

Table 2: Course Distribution by Credit Units

CREDIT UNIT	FREQUENCY (CYS)	FREQUENCY (IFT)	TOTAL
2 units	12	14	26
3 units	6	5	11
Total	18	19	37

Source: Fieldwork (2025)

The distribution shows that most courses are 2-credit unit courses, with a smaller proportion being 3-credit unit courses across both departments

4. DISCUSSION OF FINDINGS

Findings are presented in line with the study objectives. Necessary inferences are drawn from some of the findings in light of the theoretical framework of graph coloring, while observed similarities and differences between the present study and extant literature are reconciled using appropriate mathematical and computational explanations. The investigation revealed several key findings regarding the application of graph coloring to examination scheduling at FUTA. First, the DSATUR algorithm successfully generated conflict-free timetables for both departments across both semesters, with zero instances of students being scheduled for multiple examinations in the same time slot. This confirms the effectiveness of saturation-based heuristics in handling dense conflict graphs typical of university examination scheduling.

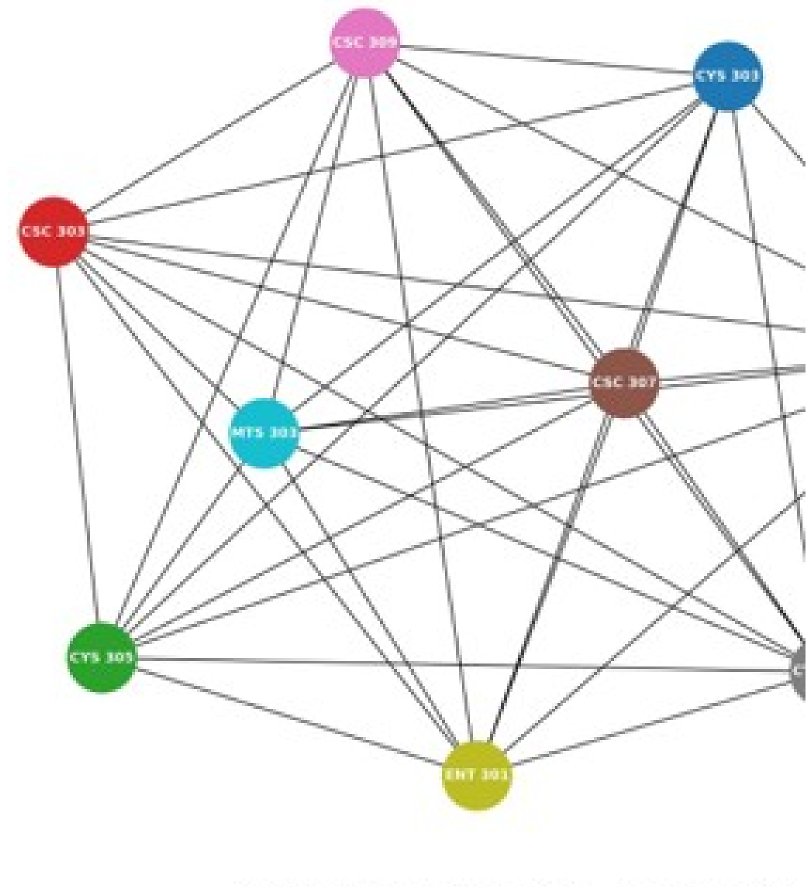

Fig. 1: Conflict Graph Visualization for Cybersecurity First Semester

The chart in Fig 1 shows the conflict graph before colouring and after the application of the DSATUR algorithm. Vertices represent courses, edges represent conflicts, and colours represent assigned time slots. The visualization clearly demonstrates how the algorithm resolves all conflicts by assigning distinct colours to adjacent vertices.

Table 3: Performance Metrics Comparison

METRIC	MANUAL SYSTEM	AUTOMATED SYSTEM	IMPROVEMENT (%)
Processing Time	3-5 days	0.67 seconds	99.9%
Conflicts Detected	5-8 per semester	0	100%
Time Slots Required	7-9	4-5	44.4%
Administrative Hours	40-60	2-3	95%

Source: Comparative Analysis, 2025

The performance comparison reveals dramatic improvements across all metrics. The automated system reduced processing time from days to less than a second, eliminated conflicts, and reduced the number of required time slots by nearly half. Also, the chromatic number for each semester was determined to be 4-5 colours (time slots), significantly lower than the 7-9 slots typically required by manual scheduling. This optimization translates to shorter examination periods, reduced venue usage, and decreased student stress. In addition, computational efficiency remained excellent even with varying graph densities. The system processed graphs with up to 19 vertices and over 50 edges in under one second, demonstrating scalability for larger institutional applications.

Course	Slot	Date	StartTime	EndTime	Da
CYS 303	1	4/8/2025	12:00	15:00	Af
CSC 301	1	4/8/2025	12:00	14:00	Af
CYS 305	2	5/8/2025	8:30	11:30	M
CSC 303	2	6/8/2025	12:00	15:00	Af
CSC 307	3	7/8/2025	8:30	11:30	M

CYS 1st semester

Course	Slot	Date	StartTime	EndTime	Da
IFT 303	1	4/8/2025	8:30	11:30	M
SEN 307	1	4/8/2025	15:30	18:30	Af
CSC 305	2	5/8/2025	8:30	11:30	M
SEN 305	2	5/8/2025	15:30	18:30	Af
CSC 315	3	6/8/2025	12:00	15:00	Af
CSC 307	4	7/8/2025	8:30	11:30	M

IFT 1st semester

Fig. 2: Distribution of Examinations Across Time Slots

The table illustrates the balanced distribution of examinations across the five time slots generated by the algorithm. This even distribution prevents overloading any single time slot and ensures optimal resource utilization.

5. CONCLUDING REMARKS

The system presented an approach of solving the curriculum timetabling problem which is depicted as NP hard problem. The approach of Graph Colouring was deployed to estimate the best possible result in the real time dataset. The application can be readily scalable to the complex timetabling problem. This would be achieved by increasing the size of the collage and by incorporating further constraints on the timetable. Graph Colouring effectively demonstrated an ability to solve complex optimization problem. Notably, this served to provide a very thorough introduction to the techniques employed and incorporated by Genetic Algorithm. The proposed system has well designed consideration of hard constraints towards scheduling.

6. CONTRIBUTIONS TO KNOWLEDGE

This research provides an informative examination timetabling system with minimal occurrences of conflicts that are common in manual systems.

REFERENCES

1. Arifin, S., Muktyas, I. B., Al Maki, W. F., & Mohd Aziz, M. K. B. (2022). Graph colouring program of exam scheduling modeling based on bitwise colouring algorithm using Python. Journal of Computer Science, 18(1), 26-32.
2. Biswas, S., Nusrat, S. A., Sharmin, N., & Rahman, M. (2023). Graph colouring in university timetable scheduling. International Journal of Intelligent Systems and Applications, 15(3), 16-32.
3. Diallo, F. P., Kaboré, A., & Savadogo, M. (2024). Optimizing the scheduling of teaching activities in a faculty. Applied Sciences, 14(20), 9554.
4. Egwuche, O. S. (2020). Examination timetabling with graph colouring for emerging institutions. Proceedings of IEEE Conference on Information Technology. Available Online at http://www.ieee.org. Retrieved November 15, 2024.
5. Gu, X., et al. (2025). From integer programming to machine learning: A technical review on solving university timetabling problems. Computation, 13(1), 10.
6. Idiege, E. E., & Eneji, S. E. (2025). Automated examination timetable for NCE programmes of Federal College of Education, Obudu. European Modern Studies Journal, 9(1). Website: www.emsj.eu
7. Malviya, A., Agrawal, B., & Kumar, S. (2024). Graph colouring algorithm for course timetable scheduling problem. ShodhKosh: Journal of Visual and Performing Arts, 5(3), 452-460.
8. Malkawi, M., Al-Haj Hassan, M., & Al-Haj Hassan, O. (2008). A new exam scheduling algorithm using graph colouring. The International Arab Journal of Information Technology, 5(1), 80-86.
9. Oke, A., Wakili, A., & Olayiwola, B. (2023). Examination timetable scheduling using graph colouring for Faculty of Science. British Journal of Multidisciplinary and Advanced Studies, 4(2), 117-143.
10. Osama Al-Haj Hassan, Osama Qtaish, Maher Abuhamdeh, and Mohammad Al-Haj Hassan (2019). A hybrid exam scheduling technique based on graph colouring and genetic algorithms targeted towards student comfort. International Journal of Advanced Computer Science and Applications, 10(3).

11. Sunday J. Agbolade, Ayinla B. I., Odeniyi L. A., & Akinola S. O. Optimisation of University Examination Timetable Using Hybridised Genetic and Greedy Algorithms: A Case Study of Computer Science Department, University of Ibadan.
12. Vyas, M. N., & Hemalatha, G. B. (2025). Exam scheduling using graph colouring. Journal of Information Systems Engineering and Management, 10(24s).
13. Welsh, D. J. A., & Powell, M. B. (1967). An upper bound to the chromatic number of a graph and its application to the timetabling problems. Computer Journal, 10(1), 85-86. Available Online at http://www.comjnl.oxfordjournals.org. Retrieved October 20, 2024.