DEVELOPMENT OF AN AUTOMATED TIMETABLE GENERATOR USING GENETIC ALGORITHM

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ABSTRACT

Educational timetabling is a major administrative activity for a wide variety of institutions. The process involves scheduling a sequence of lectures between lecturers and students in a prefixed period. However, conventional approach to timetable scheduling is very time consuming, therefore, this research addresses the issue by developing an automated timetable generator using genetic algorithm. The developed system satisfied both hard and soft constraints as well as generate a conflict free timetable with an accuracy of 98.5% and an average response time of 0.176 seconds. The results obtained for functionality, reliability, ease of use, efficiency and portability are: 95%, 65%, 80%, 80% and 85% respectively. The mutation and crossover rates are 0.01% and 0.95% respectively and the fitness value is 1 which shows that the developed timetable generator has zero number of clashes. Although, the developed system has achieved a certain level of accuracy, reliability, functionality and ease of use, however, future work should consider hybridizing GA with more advanced algorithms to obtain better results and reduce processing time.

Keywords: Genetic Algorithm, Constraints, Timetable Generator, Reliability, Ease of Use, Accuracy

1. INTRODUCTION

Timetabling is the process of allocating time for planned activities in an orderly manner to achieve a satisfactory result and it can be applied in transportation, sport, workforce and schools (Islam et al 2016). In the early days, timetable scheduling was done manually in schools, colleges and other fields of teaching by an individual or a group of people (Shabina 2015) but the approach is very time consuming and usually ends up with various classes clashing either at same room or with same teachers having more than one class at a time. Research also show that timetabling is one of the scheduling problems which is difficult to solve using conventional methods because it requires unique constraints, hence, the development of automatic timetable scheduling systems. Automatic timetabling involves scheduling a sequence of lectures between lecturers and students in a prefixed period of time automatically while satisfying various set of constraints (Nahwan and Talal 2016). A wide variety of approaches to timetabling problems have been described in the literature and tested on real data. They can be roughly divided into four types: sequential, cluster, constraint-based and meta-heuristic methods. Sequential methods assign events based on their difficulty value by using different sequential heuristic. The most common sequential heuristics are largest enrolment, largest degree and saturation degree. Each sequential heuristic has its own criteria to obtain the difficulty value of events (Junn et al., 2020). In cluster methods, the set of events is splitted into groups, which satisfy hard constraints, and then the groups are assigned to periods to fulfill the soft constraints. Constraint based approaches is a natural tool for describing as well as solving a lot of problems from various areas and its major advantage is its capability of precise declarative description of a problem using relations between variables. It is based on a strong theoretical basis and it has wide practical applications in areas of evaluation, modeling and optimization. Meta-heuristic methods are types of "higher level" general purpose algorithms that can be used with a wide range of different problem types (Jain et al. 2015). In Meta-heuristic methods one or more initial solutions employ search strategies that try to avoid local optima (Hambali et al., 2020)

Automatic timetabling systems is mostly used in higher institutions of learning such as Universities, colleges and polytechnics. It helps to allocate specific time and venue to courses in order to prevent clashes. Different approaches such as random non-ascendant method (RNA) (Luisa & Farina 2008), tabu-search (Islam et al 2016), artificial neural networks and machine learning (Prashanta et al., 2020) have been employed to develop automatic timetable generators for various schools. The shortcoming of random non-ascendant method (RNA) (Luisa & Farina, 2008) and tabu-search approaches is their inability to address some soft constraints and the presence of a lot of alterable parameters respectively. In addition, available timetable generators are unsuitable for the target usage because constraints differ from one institution to another. Hence, this research developed an automatic timetable generator for a higher institution in Nigeria using genetic algorithm. The algorithm was chosen because it is capable of determining the best schedule using fitness cost calculation.

2. RELATED WORKS

Evolutionary Algorithms are a class of direct, probabilistic search and optimization algorithms gleaned from the model of organic evolution. Genetic Algorithm is an evolutionary algorithm which involves the process of chromosome representation to generate a timetable. Shabina (2015) proposed the development of an Automated Timetable generator using Genetic Algorithm. Wiilams and Ajinaja (2019) developed a genetic Algorithm based timetable generator to find solution to the timetable problem. The developed system minimized errors and mistakes encountered timetabling. Al-Majmar and Al-Shfaq (2016) developed an improved time table generator using a modified Genetic algorithm. The research has tried to show that genetic algorithm is a powerful method for solving timetabling problem especially with some suggested improvements. The initial timetabling problem with large number of binary variables has been significantly reduced to the acceptable size by grouping of several binary variables into one gene value in the chromosome Courses and lectures were scheduled in accordance with all possible constraints and given inputs.

Meta-heuristic approach has also been employed to solve the problem of timetabling. Kuan (2018) presented a research which incorporated the meta-heuristic strategy to solve educational timetabling problem. The research experiment was conducted by comparing the quality of solutions produced by Genetic Algorithm with other meta-heuristics which have been done in the past. The experimental results suggested that Genetic Algorithm manages to produces good solutions in this domain although other algorithms are able to improve the quality of the solutions. In the research, the experiment was further investigated by comparing the performance between other meta-heuristics such as Great Deluge (GD) and Simulated Annealing (SA) algorithm. Hakan (2015) presented two meta-heuristic algorithms; Simulated Annealing and Tabu Search for solving time-tabling problem. The results show that although both algorithms are good candidates for creating timetables, Simulated Annealing has the edge both in run time and the quality of the timetable. Hambali A.M., Olasupo Y. A., and Dalhatu M. (2020) Combines Genetic Algorithm and simulated Annealing approaches to develop automatic time table generator. The algorithms were chosen to enable the user calculate the approximate solution rather than finding the optimal one in order to decrease the run time of the program while still getting an acceptable solution. The resulting system is flexible and generated a class timetable with only eight iterations.

Other approaches which have been used by previous researches for developing automatic timetable schedulers include: random non-ascendant method (RNA), tabusearch, simulated annealing, machine learning and artificial neural networks. Luisa & Farina (2008) random non-ascendant method (RNA) to automatic time-tabling. The research focused on the Spanish school timetabling problem and results showed that the RNA method is able to reduce drastically the number of unsatisfied hard constraints, and consequently the cost function. however, the shortcoming of the research is its inability to manage soft constraints effectively. Islam et al (2016) designed a system using Tabu Search Algorithm for solving timetabling problem for some departments in Southeast University. The problem was solved by using a scoring method course and examination timetabling. The system developed was able to obtain high quality solution within a short time. Prashanta et al., (2020) developed an Automatic Timetable Generator using machine learning. The Timetable Generator System allows users to generate time table for newly occurring changes in less time, with less effort and with more efficiency.

Automatic timetable scheduling was also developed by previous works as a web-based application. Tabassum et al developed a web-based timetable generator using multiple open source frameworks and libraries to boost the development process. The application successfully accomplished hard constraints to achieve a feasible and efficient timetable schedule for students and lecturers.

Two or more approaches were recently hybridized to improve the quality of automatic timetable generators. Nguyen and Nguyen (2021) investigated an approach to timetabling using swam-based algorithm named spotted hyena optimizer which is inspired by the hunting behaviour of spotted hyenas. SA and SAO algorithms were also combined to developed automatic timetabling and research show that hybridization of SAO and SA improved the performance of the system. It also indicated the efficiency of the methods over other meta heuristic methods like PSO. Kumar et al (2020) developed an automated timetable generator using a hybrid approach that combines Monte Carlo methods and surrogate modelling. Research show that the framework can give legitimate arrangements that can be utilized. Although, the system was able to generate results, the solutions that the system provided heavily depend on the running configuration and evaluation matrix. The system was hard to evaluate because the freedom for the configuration of the algorithm has provided a large number of combinations.

3. METHODOLOGY

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3.1 GENETIC ALGORITHM FOR AUTOMATIC TIMETABLE GENERATION

The developed automatic timetable generator is divided into six important modules which include: data encoding and decoding, Initial population, fitness computation, crossover evolution, mutation and new Population as shown in Figure 1.

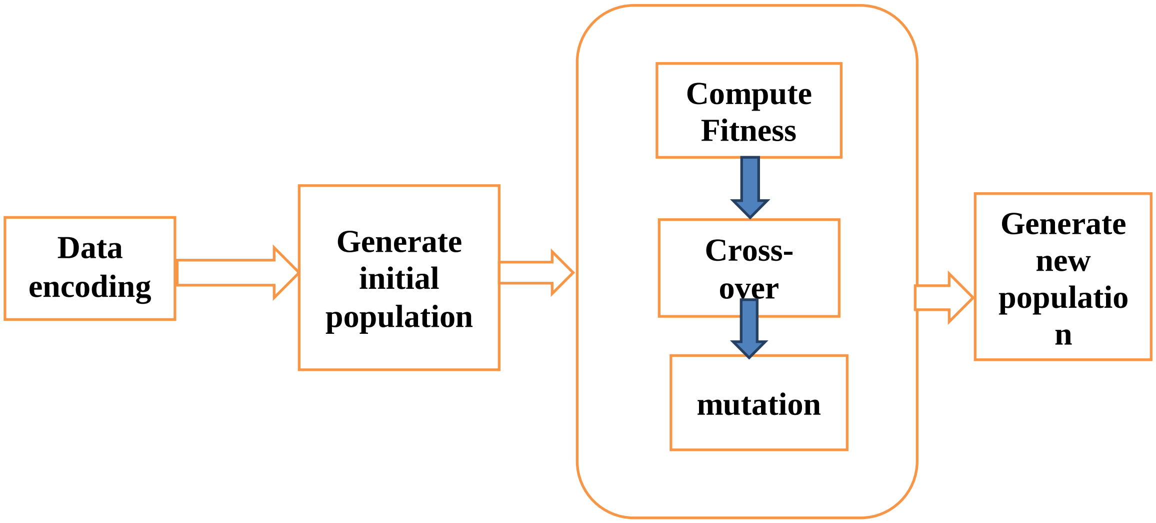


Figure 1: Flow diagram of the automatic timetable generator

1. **Data encoding and decoding:** The total numbers of classes to be scheduled were obtained by adding the number of student groups and multiplying it by the number of modules each student group is enrolled in. The following hard constraints were considered for each class scheduled:

- One Lecturer teaches one class at a time
- A student only attends a class at a time
- Two classes must not be held in one room at the same time
- Maximum number of hours allotted for a day cannot be exceeded.

2. Initial population: The timetable generator was built using the following: the lecture rooms denoted by roomID, lecturers denoted by LecturerID, time represented by TimeID, courses denoted by CourseID and student groups represented by StudentID.

3. Compute Fitness: The best solution was determined using the fitness function formula (Thakare et al., 2020) shown in equation 1; where, *x* = timetable under evaluation, *w* = number of Constraints, *t* = total fitness value.

$$F(x) = \frac{\sum_{i=1}^{n} xi \neq W}{t} \qquad 1$$

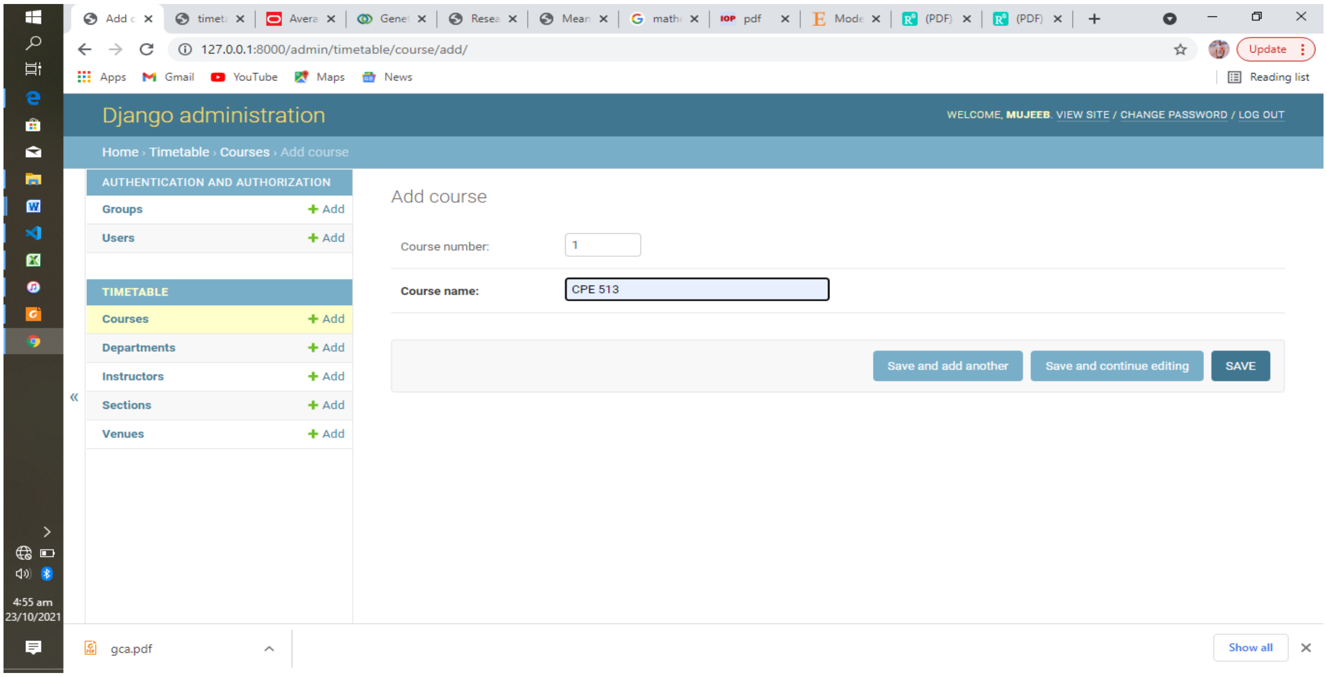
4. **Crossover Evolution:** A new population was created in this stage based on older population. It uses two chromosomes and created X new chromosomes. The two chromosomes were splitted in parts and new chromosomes were created from these parts.

5. Mutation: The values of the genes were changed randomly to generate new solutions which offer a new point of view for the fitness function. This technique ensures that all the mutated individuals are valid.

6. New Population: A new population of original solution was created from crossover and mutation.

3.2 SYSTEM IMPLEMENTATION

The data used for the implementation of the developed timetable generator was obtained from the faculty of Engineering of a public institution in Nigeria. The data collected include: sixty-eight courses, fifty lecturers and twenty classrooms. The system’s interface was designed using visual studio code integrated development environment. Figure 2 and 3 show the screen shot of the course section page and the generated timetable for two lecturers and two classrooms at different time.



127.0.0.1:8000/admin/timetable/course/add/

Django administration

WELCOME, MUJEEB. VIEW SITE / CHANGE PASSWORD / LOG OUT

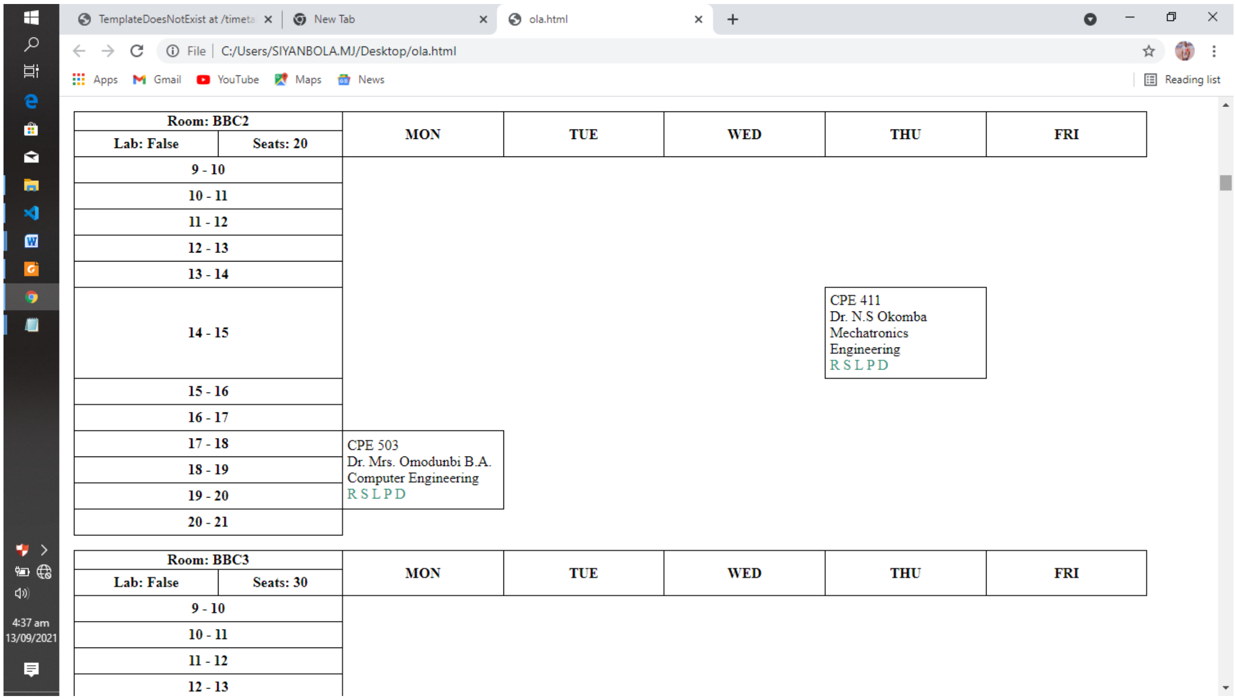
Home › Timetable › Courses › Add course

Add course

Course number: 1

Course name: CPE 513

Figure 2: screenshot of Course section page


TemplateDoesNotExist at /timeta
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YouTube
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17 - 18		CPE 503 Dr. Mrs. Omodunbi B.A. Computer Engineering R S L P D				
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Figure 3: Generated timetable from the developed timetable generator

4. RESULT AND DISCUSSION

The developed timetable generator was tested and evaluated in orer to ensure that the system was able to achieve efficient timetabling and reduced processing time. The hard constraints were tested to ensure that all the solutions obtained were valid. Result from qualitative evaluation is shown in table 1 and Figure 4. The developed system was tested by respondents which include lecturers and technologists from the institution. The users rated the system performance based on the following metrics: functionality, reliability, ease of use, efficiency, and portability with the following results: 95%, 65%, 80%, 80% and 85% respectively as shown in Figure 4. From empirical evaluation, it was deduced that the developed system has an accruracy of 98.5% and an average response time of 0.176 seconds. The mutation and crossover rates are 0.01% and 0.95% respectively. The fitness value is 1 which shows that the developed timetable generator has zero number of clashes.

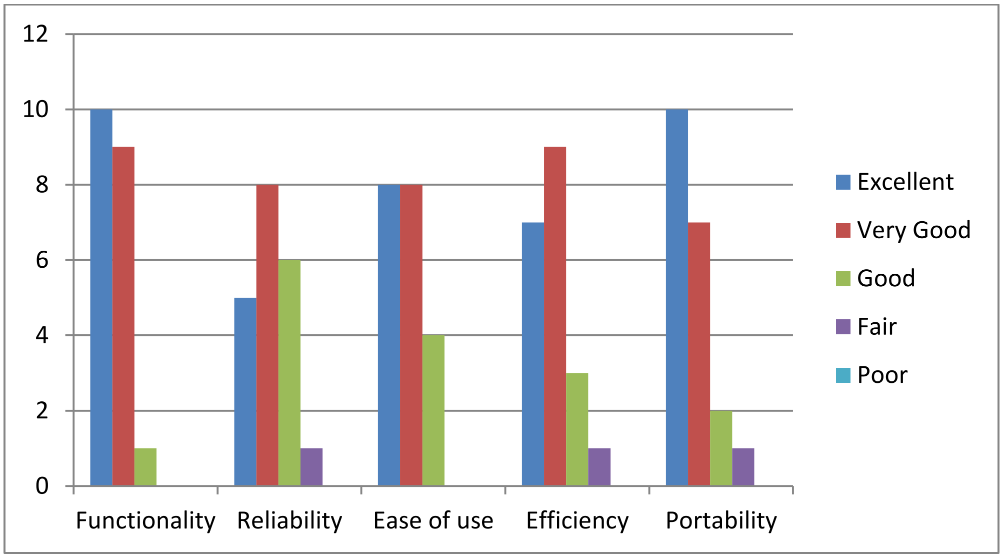

Figure 4: Performance evaluation chart for the developed timetable generator

5. CONCLUSION

This research designed an automated timetable generator using genetic algorithm. The developed system was implemented for academic timetable generation in a Nigerian University and results show that a high level of accuracy, reliability, efficiency, functionality and ease of use were achieved. However, future research can combine Genetic Algorithm to other heuristic methods for the development of automatic timetable generators to obtain improved results and reduced processing time.

6. ACKNOWLEDGEMENTS

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