EXAMINATION TIMETABLING USING GENETIC ALGORITHM CASE STUDY: KUiTTHO

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ABSTRAK

Algoritma Genetik merupakan salah satu kaedah yang popular dalam penyelesaian pengoptimuman. Ia telah diiplementasikan dalam pelbagai aplikasi seperti penjadualan. Aliran AG menggunakan proses pemilihan, persilangan dan mutasi terhadap populasi dari kromosom. Kertas ini membincangkan teknik yang berkesan menggunakan Algoritma Genetik untuk aplikasi penjadualan. Masalah jadual peperiksaan adalah satu daripada aplikasi dalam penjadualan. Pada satu aspek, ia bertujuan untuk mengatur slot masa pelajar yang ingin menduduki peperiksaan. Faktor ini penting bagi melicinkan perjalanan peperiksaan agar tiada pelajar yang menduduki lebih dari satu peperiksaan dalam slot masa yang sama. Di samping itu, beban subjek juga ditentukan kepada kurang dari tiga peperiksaan secara berturutan. Permasalahan penjadualan peperiksaan di Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO) diperkenalkan dan prototaip sistem telah dibangunkan menggunakan bahasa pengaturcaraan Java. Prototaip yang dicadangkan mempunyai pelbagai penyelesaian yang munasabah terhadap pengguna.

ABSTRACT

Genetic Algorithm (GA) is one of the most popular optimization solutions. It has been implemented in various applications such as scheduling. The flows of GA are using selection, crossover and mutation operators applied to populations of chromosomes. This paper reports the powerful techniques using GA in scheduling. Examination timetabling problem is one of the applications in scheduling. In one aspect, it deals with students such that it fulfils the process time slot. These aspects are important for the examination can be done in a smooth way and no students can sit more than one exam in a same time slot. The other constraint is the student workload should be arranged less than three exams in a row. The examination timetabling problem at Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO) is introduced and the prototype has been developed using Java language. The prototype suggested several feasible solutions to the user.

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DEDICATION

To my mother Tharina Bt Abdullah,
for his love, patience and support.

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LIST OF ABBREVIATIONS

ACS	Ant Colony System
BSc. IT	Bachelor of Science Information Technology
CBR	Case Base Reasoning
EPP	exam proximity problem
ETS	Examination Timetabling System
FIFO	First In First Out
FTMM	Fakulti Teknologi Maklumat Dan Multimedia
GA	Genetic Algorithm
GDA	Great Deluge Algorithm
GUI	graphic user interface
HC	Hill Climbing
IS	Information System
JSDK 1.3.1_05	Java Software Development Kit version 1.3.1_05
KUiTTHO	Kolej Universiti Teknologi Tun Hussein Onn
MA	Memetic Algorithm
NP	Nondeterministic Polynomial
ODBC	Open Database Connectivity
PMRP	Point to Multipoint Routing Problem
TEDI	Timetabling Tool for Educational Institutions
UPJJ	Unit Pendidikan Jarak Jauh
UUM	Universiti Utara Malaysia

CHAPTER 1

INTRODUCTION

The aim of this paper is to discuss on the project background that mainly involves in examination timetabling using Genetic Algorithm (GA). The problem statement, the objective and the significance of the study and scope will be discussed in this section.

1.1 Background Study

Scheduling problems is a difficult task in the artificial intelligence. It deals with the allocation of limited resources to tasks over time (Pinedo, 2002). The process is to optimize one or more objectives. The measurement methods which is known as computationally NP (Nondeterministic Polynomial) is the most difficult parts that the researchers faced on the scheduling problems which is lacking with the elements of the polynomial time algorithm.

It is important to plan and manage the schedule for a better end results. For instance, in the higher learning institute, it is a normal practice for the administrator to prepare and design the class scheduling before students begin their new semester. This effort lead for an effective end results from a proper management of the time scheduling systems for the classes arrangements. Apart from scheduling the classes time arrangements, the examination timetabling for the students also lead for an effective management systems in a university. However, in a daily practice, this effort is a common management problem occurs in most of the educational institutions.

Examination timetabling should focus on aspects of time, place, time slot and person in charge in the examination halls. This workload has been the most difficult task faced by the administrators in the educational institutions since it's requires many resources to solve various exam matters for each year. Timetabling can be defined allocating a set of examinations into a given set of classrooms over a limited number of time periods to avoid the occurrence of conflicts of interests between two examinations (Yang and Petrovic, 2004). These aspects are important for a smooth operation of the examination and avoiding redundancies with any other examination take place in the same time and same place. A good scheduling technique leads for the optimization of the entire aspect.

Timetabling problem is a part of scheduling which contains a set of events such as exams and lectures time slots. The constraints can be classified as hard and soft constraints with the purpose to avoid the redundancies of students, subjects and exams places. The hard constraints type is a situation when no students are allocated

to more than one exam at the same time. A soft constraint is a situation where there is no student with three exams in a row. As a result of failure, penalty will be given for both of the constraints. The hard constraint will be used for the higher penalty while lower penalty will be initialized to the soft constraint.

Timetabling problems involve in feasible assignment of users to time slots that are distributed over a period of time, based on a set of constraints. Problems of time based planning and combinational optimizations, which tend to be solved with cooperation of search and heuristics to get optimal or near optimal solutions (Fang, 1992). This problem should be solved to ensure the requirements and constraints are fulfilled within a limited time.

For this study, GA has been used in the prototype development. This method have been used in the science and engineering fields by adapting algorithms to solve practical problems and as computational models of natural evolutionary systems (Mitchell, 1999). GAs can solve searching and optimization problems based on genetic process. According to Fang (1992), GA is a powerful technique in optimization problems (mutation and crossover operators applied to populations of chromosomes) either from the domain to specific aspects of a problem (the evaluation function for the chromosomes).

GA is a search algorithm based on a simple idea from biology "survival of the fittest" (Michalewicz, 1999). GA performs a directed search of a solution space in order to find an optimal solution for some problem. They have been used for many

different applications including scheduling, predicting the stock market and creating art.

In GAs method, the fittest is active based on the selection mechanisms and natural genetic in searching algorithms. This process happens among string of structures which represents the information structures. These structures will be change based on non-randomly but stochastically in searching the algorithms.

In fulfilling the requirement of this study, KUiTTHO (Kolej Universiti Teknologi Tun Hussein Onn) examination timetabling will be chosen as a case study. Student is required to sit for not more than one exam at same time slot. If possible, the prototype can arrange less than three exams in a row. The data consists of 178 students from Bachelor of Science Information Technology (BSc. IT) program with initially consists of 18 subjects. This information will be used as a case study in designing and developing the prototype.

1.2 Problem Statement

Currently, examination timetable scheduling at KUiTTHO is done manually, where the time task has been created two month earlier before the exam. The time consuming process require sequences of the manual steps. This process used the clustering and heuristic method. The subject is locating in the empty time slot and empty place randomly. This is to avoid redundancies and re-scheduling process. In

addition, rescheduling process is time consuming and may affect on the lessons planning and all staff involved.

1.3 Objective

The objectives of the study are as the following:

- To optimize the slot and arrangement timetabling process
- To develop an Examination Timetabling System (ETS) prototype in Java in the implementation of GA methods
- To evaluate the developed prototype in term of parameters setting

1.4 Significance of Study

GA is a planning and combinational optimization method based on time to obtain the optimum solutions for developing ETS prototype. It can produce a different type of possibility with different sets of parameter. A comparison will be made between these possibilities in generating feasible and optimal results of the examination timetable. Thus, the prototype has been developed as an alternative approach to reduce cost and time in designing exams timetables for Fakulti Teknologi Maklumat Dan Multimedia (FTMM) at KUiTTHO.

1.5 Scope

In this project, GA method has been implemented at FTMM in KUiTTHO. The real BSc. IT examination data for first semester session (2004/2005) were used to implement the ETS. The result of this study (timetable) is representing in the form of chromosomes.

1.6 Thesis Overview

This project report is divided into five chapters. Chapter one discuss about the introduction that explains the background of the study, problem statement, objective, and the significance of study and scope. In the second chapter, literature review of several related papers and applications will be described. There are six subtopics, related with scheduling or timetabling problem solving approach and GA's application. Chapter three discuss on the methodology approach that has been used for this project. Chapter four discussed on the outcome and the findings derived from this project. The results and discussions are based on the prototype that has been developed. Chapter five concludes and discuss of project report.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section discusses on the several related papers on the application of timetabling. The investigating approaches and techniques used to solve any problem arise will be explained in this chapter. It reviews scheduling problem and timetabling problem using GAs and others application.

Timetabling can be considered as a scheduling problem. The constructions of timetables is very difficult with a lot of constraints should be followed. GAs has been used quite successful in the timetabling problem. However, there are several techniques used to find the optimization solution in timetabling problem such as tabu search, ant algorithm, simulated annealing and others. The main objective is to find schedules to satisfy a numbers of hard and soft constraints.

2.2 Applications of GAs in Scheduling Problem

There are many kinds of problems in the domain of scheduling. Scheduling is a resources allocation problem which exists virtually in every type of organization (Brown *et al.*, 1995). The use of GA in scheduling is already proven to be very successful (Ghazali and Ramli, 2004). They review scheduling of manpower available in transportation services such as trains and buses. Transportation is important services to fulfil the process of sending goods or people from one destination to another. If the resources are insufficient to meet demand, deliveries of goods may be delayed. They suggest a framework for a driver using GA, which is efficient performance and high quality schedule of trips. It is also satisfies both of management's and driver constraints. Many approaches have been applied to solve the driver scheduling through mathematical and heuristics. The feasible and efficient solution has been given by heuristic technique that was seen in the GA.

Helm *et al.* (2002) compared three scheduling techniques representative of "old" or standard technologies, evolving technologies and advanced technologies. The problems are the complications of scheduling long term upgrades and refurbishments essential to maintaining expensive capital assets. They concentrate on the costs of being able to do maintenance work. Genetic programming produces 60% less costly while Constraint programming is 31% using a standard technology as the baseline technique.

The most important part of a hardware and software co design system is the scheduler which is needed in order to determine if a given hardware and software partitioning is suitable for a given application (Grajcar, 2000). They employ a dataflow model for scheduling a computation. A formal model for the conditional scheduling problem has been given which provides for multiple optimization possibilities. It allows multiple schedule optimizations and a new efficient heuristic approach based on GAs and list scheduling. The genetic list scheduler performs very well for the unconditional problem and typically returns schedules lying within 5% of the optimum. The length of the conditional schedule exceeds the length of the unconditional one only by about 10%. The algorithm performs well both in terms of running speed and result quality although the implementation misses some important features.

Baggio *et al.* (2004) presented some of the problems of using scheduling results in ordering cases in a workflow. GAs is a suitable technique to modelling the uncertainties on the cases' processing times and routing. It is a suitable technique that consists of making a guess on the execution times and routes. A GA implementation should be feasible for medium sized workflows. Simulation results show that for almost all workloads rules are statistically considerably better than the commonly used First In First Out (FIFO) rule regarding the number of late jobs.

According to Galiasso and Wainwright (2001), an application of the Point to Multipoint Routing Problem (PMRP) with single split paths is introduced. The application called the Message Scheduling problem is the process of scheduling,

which is a set of requests through a network where each request has a single source and multiple destinations. This experiment was using GA and a heuristic Steiner tree algorithm for finding near optimal solutions. The hybrid algorithm is not only treats each request as a whole, but also allows up to two paths for transmitting the request bandwidth. The chromosome was designed to accommodate not only the option of multiple paths for a request, but how to split the bandwidth. The results turned out to be superior because of using a different chromosome representation of the problem. It showed that allowing transmission requests to be routed using two paths improved the usability the network.

2.3 Timetabling Problem Solving Approach

Timetabling problem is a special case of scheduling problem. It's involves scheduling a number of students, teachers, and classrooms into a fixed set of periods. An optimal schedule would be one where no teacher, student or classroom is used more than once in any given period. Timetabling problems occur in course or subjects scheduling and finals scheduling at educational institutions. The timetabling problem can be described as finding a schedule where students, teachers, and classrooms combination within the same period have a minimal number of overlapping elements.

According to Melicio *et al.* (2004), they find out the three main categories of timetabling problem:

1. Class/Teacher timetabling. The weekly scheduling of all classes, avoiding teachers meeting two classes in the same time and vice-versa.
2. Course timetabling. The weekly scheduling for all lessons of a set of courses, minimizing the overlaps of lessons of courses having common students.
3. Examination timetabling. The scheduling for the exams of a set of courses, avoiding overlapping exams of courses having common students, and spreading the exams for the students as much as possible.

They describe about assigning a set of lessons to time slots within a time period (typically a week), satisfying a set of constraints of various types. They presented two neighbourhood approaches to the timetabling problem. The neighbourhood operators that have many names depend on the domain where they are referred. Single move means that they exchange the value of one variable, while the double move signifies that the values of two variables are exchanged. These operators can have other designations, like insertion move or pair wise interchange depending mainly on the domain where they are applied.

Any search algorithm needs for certain parts to be problem specific. It is very important the way these parts are implemented. A fine tuning of parameters will never balance a bad definition of the solution set, of the neighbourhood or the cost function. They have been comparing and testing using real data from three

Portuguese schools of different size and complexity. The application of the correct neighbourhood operator has been observed to the successful of the search algorithm.

Timetabling problems always requires the processing of hard and soft constraints. Hard constraints are conditions that must be satisfied. However, soft constraints may be violated but should be satisfied as much as possible. Abdennadher and Marte (2000) proposed how to model timetabling problem as a partial constraint satisfaction problem and gives a concise finite domain solver implemented with Constraint Handling Rules. They were developed the prototype that needs only a few minutes to create a timetable while manual timetabling usually takes a few days. The prototype is improving efficiency by reusing parts of the timetable of the previous year.

Muller (2002) investigates a constraint model and a solution algorithm for interactive timetabling. They suggested a generic model for weekly periodical and lecture timetabling problems consisting of a set of resource, activities and dependencies between it. Combination of the local search the backtrack-based search for solving constraints satisfaction problems is been presented. They required working with feasible timetables and demanded the timetable not to differ much from one feasible solution to another during the search. They discussed about graph colouring and evolutionary approach. The basic motivation had been design based on GA method with interactive features for solving school timetabling problems. The implementation can be easily extended to cover additional hard and soft constraints.

A steady state genetic algorithm for solving a multi-constraint university course timetabling problem was presented by Ozcan and Alkan (2002). They have been developed a configurable tool, graphic user interface (GUI) named Timetabling Tool for Educational Institutions (TEDI) for Faculty of Engineering and Architecture at Yeditepe University. It's very powerful and interactive for entering input data and viewing the output. The optimal timetable for the experiment data is much quicker than manually. Ozcan and Alkan (2003) are also proposed Memetic Algorithm (MA) for timetabling. They discuss about a variety of new operators that can be applied in evolutionary algorithms for other timetabling problems such as exam timetabling. The experiments confirm that the crossover operator is the traditional uniform crossover operator and the best mutation operator is the violation directed operator that is applied onto a block rather than the whole individual. Genetic search combined with hill climbing achieves the best performance. The experiments are using TEDI, show trans-generational MA yields better results than the steady state MA.

Rossi-Doria and Paechter (2004) suggested a metaheuristic approach to the university course-timetabling problem using a MA. They tested the algorithm on 20 instances proposed for the International Timetabling Competition. Results are encouraging and perfect solutions without constraint violations, hard and soft, exist for all the 20 instances. Therefore, the evolutionary computation with the help of local search can compete with successful algorithms.

REFERENCES

Abdennadher, S. & Marte, M. (2000). *University Course Timetabling Using Constraint Handling Rules*. Retrieved January, 2005, from http://www.pms.informatik.uni-muenchen.de/mitarbeiter/marte/publications/Abdennadher-Marte-JAAI-2000.pdf

Baggio, G. Wainer, J. & Ellis, C. (2004). Applying Scheduling Techniques To Minimize The Number Of Late Jobs In Workflow Systems. *SAC '04, March 14-17, 2004, Nicosia, Cyprus. 2004 ACM Symposium on Applied Computing, pp. 1396-1403.*

Brown, D. E. & Scherer, W. T. (1995). *Intelligent Scheduling Systems*. Kluwer Academic Publishers, 101 Philip Drive, Assinippi Park, Norwell, Massachusetts 02061, USA, ISBN 0-7923-9515-8.

Burke, E. K. & Newall, J. P. (2002). Enhancing Timetable Solutions With Local Search. *PATAT 2002 Proceedings of the 4th International Conference on the Practice and Theory of Automated Timetabling*. Retrieved February, 2005, from http://ingenieur.kahosl.be/vakgroep/IT/Patat2002/ExaminationTT/newall.pdf

Carter, M. W. (2000). A Comprehensive Course Timetabling And Student Scheduling System at the University of Waterloo. *PATAT 2000 Proceedings of the 3rd International Conference on the Practice and Theory of Automated Timetabling*. Retrieved January, 2005, from http://www.mie.utoronto.ca/staff/profiles/carter.html

Erben, W. & Song, P. Y. (2003). *A Hybrid Grouping Genetic Algorithm For Examination Timetabling*. Department of Computer Science, FH Konstanz – University of Applied Science, Konstanz, Germany. Retrieved December, 2004, from www.asap.cs.nott.ac.uk/patat/patat04/487.pdf

Fang, H. L. (1992). *Investigating Genetic Algorithms for Scheduling*. Unpublished Thesis: MSc. University of Edinburgh.

Filho, G. R. & Lorena, L. A. N. (2000). *A Constructive Evolutionary Approach To School Timetabling*. Retrieved December, 2004, from www.lac.inpe.br/~marcos/arsig2/CGA-timet-EVOCOP.pdf

Galiasso, P. & Wainwright, R. L. (2001). A Hybrid Genetic Algorithm For The Point To Multipoint Routing Problem With Single Split Paths. *Mathematical and Computer Sciences Department, The University of Tulsa, USA. SAC 2001, Las Vegas, NV. 2001 ACM, pp. 327-332.*

Ghani, T. A. Khader, A. T. & Budiarto, R. (2004). Optimizing Examination Timetabling using A Hybrid Evolution Strategies. *2nd International Conference on Autonomous Robots and Agents, December 13-15 2004 Palmerston North, New Zealand.*

Ghazali, N. H. & Ramli, R. (2004). Past Solutions Of Driver Scheduling And A Promising Path Via Genetic Algorithm. *Seminar Kebangsaan Sains Pemutusan 2004, pp. 385-392.*

Grajcar, M. (2000). Conditional Scheduling for Embedded Systems Using Genetic List Scheduling. University of Passau. *ISSS 2000, Madrid, Spain. IEEE 2000, pp. 123-128.*

Gy'ori, S. Petres, Z. & Varkonyi-Koczy, A. R. (2001). Genetic Algorithms in Timetabling. A New Approach. *MFT Periodika 2001-07. Hungarian Society of IFSA, Hungary, 2001.* Retrieved February, 2005, from http://www.mft.hu/hallg/200107.pdf

Helm, T. M. Painter, S. W. & Oakes, W. R. (2002). A Comparison Of Three Optimization Methods For Scheduling Maintenance Of High Cost, Long-Lived Capital Assets. *Proceedings of the 2002 Winter Simulation Conference, pp. 1880-1884.*

Lalescu, L. & Badica, C. (2003). Timetabling Experiments Using Genetic Algorithms. *Timetabling Experiments Using Genetic Algorithms, prezentata la TAINN'03, Canakkale, Turcia, 2003.* Retrieved February, 2005, from http://software.ucv.ro/Cercetare/Inginerie_ Software/inginerie_software.html

Melicio, F. Caldeira, J. P & Ruso, A. (2004). Two Neighbourhood Approaches To The Timetabling Problem. *PATAT 2004 Proceedings of the 5th International Conference on the Practice and Theory of Automated Timetabling.*

Merlot, L. T. Boland, N. Hughes, B. D. & Stuckey, P.J. (2002). A Hybrid Algorithm For The Examination Timetabling Problem. *PATAT 2002 Proceedings of the 4th International Conference on the Practice and Theory of Automated Timetabling.*

Michalewicz, Z. (1999). *Genetic Algorithms + Data Structures = Evolution Programs; Third, Revised and Extended Edition.* New York, New York: Springer-Verlag.

Mitchell, M. (1999). *An Introduction to Genetic Algorithms*, MIT Press, Cambridge, Massachusetts, London, England, ISBN 0-262-13316-4 (HB), 0-262-63185-7 (PB).

Mukherjee, S. N. (2001). *Timetabling Using Cellular Genetic Algorithms With Adaptive Mutation Operators*. Unpublished Thesis: Final year dissertation, University of York.

Muller, T. (2002). *Some Novel Approaches To Lecture Timetabling*. Charles University, Faculty of Mathematics and Physics, Czech Republic. Retrieved December, 2004, from http://kti.mff.cuni.cz/~muller/lt02_na.pdf

Nunamaker, Jr. J. F. Chen, M. & Purdin, T. D. M. (1991). System Development In Information Systems Research. *Journal of Management Information Systems/Winter 1990-91, Vol. 7, No. 3, pp. 89-106.*

Ozcan, E. & Alkan, A. (2002). *Timetabling Using A Steady State Genetic Algorithm*. Yeditepe University, Department of Computer Engineering, Istanbul/Turkey. Retrieved December, 2004, from http://cse.yeditepe.edu.tr/~eozcan/research/papers/PATAT2002.pdf

Ozcan, E. & Alkan, A. (2003). *Memetic Algorithms For Timetabling*. Yeditepe University, Department of Computer Engineering, Istanbul/Turkey. Retrieved December, 2004, from http://cse.yeditepe.edu.tr/~eozcan/research/papers/CEC03.pdf

Pinedo, M. (2002). *Scheduling Theory, Algorithms, and Systems Second Edition*, Prentice Hall, Upper Saddle River, New Jersey 07458, ISBN 0-13-028138-7.

Rossi-Doria, O. & Paechter, B. (2004). *A Memetic Algorithm For University Course Timetabling*. School of Computing, Napier University, Edinburgh, Scotland. Retrieved December, 2004, from http://iridia.ulb.ac.be/~meta/newsite/downloads/co2004_dam.pdf

Rubio, R. G. & Munoz, D. P. (2004). A Timetable Production System Architecture For Courses And Exams. *PATAT 2004 Proceedings of the 5th International Conference on the Practice and Theory of Automated Timetabling.*

Santos, H.G. Ochi, L. Z. & Souza, M. J. F. (2004). A Tabu Search Heuristic With Efficient Diversification Strategies For The Class/Teacher Timetabling Problem. *PATAT 2004 Proceedings of the 5th International Conference on the Practice and Theory of Automated Timetabling.*

Sheibani, K. (2002). An Evolutionary Approach For The Examination Timetabling Problems. *PATAT 2002 Proceedings of the 4th International Conference on the Practice and Theory of Automated Timetabling.*

Wong, T. Cote, P. & Sabourin, R. (2004). A Hybrid MOEA For The Capacitated Exam Proximity Problem. *IEEE Congress On Evolutionary Computation (CEC 2004), Portland, Oregon, June 20-23, pp. 1495-1501, 2004.*

Yang, Y. & Petrovic, S. (2004). A Novel Similarity Measure For Heuristic Selection In Examination. *PATAT 2004 Proceedings of the 5th International Conference on the Practice and Theory of Automated Timetabling.*

Yasin, A. Puteh, N. & Tahir, H. (2002). Examination Timetabling With Genetic Algorithms. *Jurnal Tek. Maklumat & Sains Kuantitatif, UiTM, Jilid 4, Bil (1), pp. 11-24.*