Certificate

1293/12.2.3/LL/2010

this is to certify that

ADE JAMAL

has participated on

11th Seminar on Intelligent Technology and Its Applications 2010

as:

PRESENTER

Paper Title:

A Three Stages Approach of Evolutionary Algorithm and Local-Search for Solving the Hard- and Soft Constrained Course Scheduling Problem

Surabaya, October 9th 2010

General Chairman of SITIA 2010

Dr. I Made Yulistya Negara, ST, M.Sc.

NIP. 1970 07 12 1998 02 1001

SITIA 2010

The 11th Seminar on Intelligent Technology and Its Applications

PROCEEDINGS

SITIA 2010

ISSN: 2087-331X
Volume 11
Abstract Proceedings Edition

October 9, 2010
Robotic Building, Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia

PUBLISHED BY

Electrical Engineering Department

Faculty of Industrial Technology

Institut Teknologi Sepuluh Nopember (ITS)

Campus ITS, Keputih, Sukolilo

Surabaya 60111

ISSN 2087-331X

The 11th Seminar on Intelligent Technology and Its Applications

Proceedings of the 11th Seminar on Intelligent Technology and Its Applications

SITIA's Proceeding is published once every year

COMMITTEE OF SITIA 2010

Honorary Chairman:
Prof. Ir. Priyo Suprobo, MS., Ph.D.
Rector of Institut Teknologi Sepuluh Nopember (ITS)

General Chairman:
Dr. I Made Yulistya Negara, ST., M.Sc.

Technical Committee:

Prof. Dr. Mohammad Nuh (ITS)
Prof. Dr. Soebagio (ITS),
Prof. Dr. Ontoseno Penangsang (ITS),
Prof. Dr. Mauridhi Hery Purnomo (ITS),
Prof. Dr. Abdullah Alkaff (ITS),
Prof. Dr. Achmad Jazidie (ITS),
Prof. Dr. Moh. Ashari (ITS),
Prof. Dr. Imam Robandi (ITS),
Prof. Dr. Adi Soeprijanto (ITS),
Prof. Dr. Gamantyo Hendrantoro (ITS),
Prof. Dr. Tsuyoshi Usagawa (Kumamoto University, Japan),
Prof. Dr.Ir. G.J. Verkerke (Groningen, Netherlands),
Dr. Ir. M.H.F. Wilkinson (Groningen, Netherlands),
Prof. Dr. T. Nakamoto (Tokyo Institute of Technology, Japan)
Dr. I Ketut Eddy Purnama (ITS),
Dr. M. Rameli (ITS),
Dr. Wirawan (ITS),
Dr. Ari Santoso (ITS),
Dr. Djoko Purwanto (ITS),
Dr. Achmad Affandi (ITS),
Dr. Achmad Arifin (ITS),
Dr. M. Rivai (ITS),
Dr. Moch. Hariadi (ITS),
Dr. Tri Arief Sarjono (ITS),
Dr. Son Kuswadi (ITS),
Dr. Titon Dutono (ITS),
Dr. Dadet Pramadihanto (ITS),
Dr. Endra Pitowarno (ITS),
Dr. Agus Zaenal Arifin (ITS)

Organizing Committee

Atar Fuady Babgei
Pranata Ari Baskoro
Riyan Sujatmiko
Kevin Nyoman Putra
Aryo Nugroho
Andi Nur Arief Wibowo
Gumilang Wicaksono
Median HP
Niko Permana R.W
Febri Ardianto
Rizky Pratama Putra
Radika Henry Wijaya
Fery Efendi Hermawan
Siti Aisyah
Diah Kusumawati
Alfina Zuzzida
Ivan Karsten
M. Nur Rohman
Harno Pratomo
M. Ikhsan
Debby Pratiwi Meiyesti T.

PREFACE

Dear Colleagues,

I am honored to welcome you to the 11th Seminar on Intelligent Technology and Its Applications (SITIA). This annual seminar is organized by **Electrical Engineering Department, Institut Teknologi Sepuluh Nopember (ITS) Surabaya**. The objective of this seminar is to promote the fruitful growth of researches in various fields in Electrical Engineering and its related fields presented in international oral presentation, domestic oral presentation, and poster presentation. This seminar also provides forum for researchers, scientists, and engineers to exchange ideas and their current achievements.

In this international seminar, we have received **140 paper submissions** categorized into five groups: **Computer Engineering and Telematics, Control System, Multimedia Telecommunication, Industrial Electronics,** and **Power System**. There were **56 papers** of **Biomedical Engineering** group that were diverted to another international seminar, **International Conference on Biomedical Engineering (BME Days) 2010**. Hence, in total we have received **196 papers**. This number significantly increased, compared to the previous SITIA.

During the seminar, **30 papers** will be presented in the international presentation session, **62 papers** to be in the domestic presentation session, and **48 papers** will be in the poster presentation.

Last, the success of this seminar is due to the effort of many people especially students of Electrical Engineering Department of ITS which we gratefully acknowledge. We must thank also to the authors whose papers are presented in this seminar, the invited speakers, and all parties that we are not able to mention here.

We wish you all an exciting seminar and an unforgettable stay in Surabaya. We hope to meet you again in the next seminar, The 12th Seminar on Intelligent Technology and Its Applications 2011.

Surabaya, October 9th 2010

General Chairman of SITIA 2010

Dr. I Made Yulistya Negara, ST., M.Sc.

NIP. 19700712 199802 1 001

118

A Three Stages Approach of Evolutionary Algorithm and Local-Search for Solving the Hard- and Soft Constrained Course Scheduling Problem

Ade Jamal
Department of Informatics Engineering, Faculty of Science and Technology, University Al-Azhar Indonesia, Jakarta 12110, Indonesia, email: adja@uai.ac.id

Abstract *- Course scheduling problem studied herein is categorized as an optimization problem which is subjected to two kinds of constraints. The first type is hard constraint which is necessary to be fulfilled and the second type is soft constraint which is preferably to be satisfied. This paper presents a strategy to attack this two type constrained scheduling problem which is a continuation work of the previous research where only hard constraint was taken into account. Two algorithms used in this paper, namely evolutionary algorithm and local search (modified hill-climbing method) had been investigated in the previously published work and based on its strength and weakness a three stage approach is proposed. The presented three stage strategy is quietly different than the usual approach, i.e. a single and two stage approachs.*

Keywords: *evolutionary algorithm, local search, optimization, course scheduling.*

1. INTRODUCTION

The course scheduling problem is considered as an NP-complete problem [1, 2] which is quite difficult and time-consuming to solve. Constructing a course schedule involves assignment of a set of classes or events taught by certain lecturers into time and rooms slots, and subjected to some constraints. Building a course schedule is one of the main challenges at university that must be faced by academic administrator every semester. This problem has been the subject of extensive research effort due to its complexity and wide application such as school timetables, exam scheduling and course scheduling.

The course scheduling problem is a multiple dimensional combinatorial optimization problem that is subjected to multiple constraints. These constraints are categorized in two types. The first type is a hard-constraint, which should be fulfilled without any exception. The second constraint type is called soft-constraint that is desired to be satisfied as many as possible but not absolutely essential.

There are various ways to deal with these two different constrains. Some researchers solved these two constraints simultaneously. For example Al Betar et al in [1] fixed three hard constraints in their representation model and soft constraints were incorporated in the same objective function. Others have tried a two stage approach where the first stage eliminates violations of hard constraints, and then in the second stage they attempts to minimize violations of soft constraints while keeping the number of hard constraint violations zero [3,4,5,6].

In this paper we will present a three stages approach. The preceding work [7] presented the initial stage where course schedule solution has been sought considering only hard constraints by means of evolutionary algorithm. Starting form this solution, we will apply a modified Hill-Climbing algorithm which has been used in the previous work[8] to improve the solution by taking into account the soft constraints while keeping satisfaction of hard constraints.

This paper is organized as follows: section two described the course scheduling problem including the two types of constraints and the representation model. Section three discuses the algorithms and its applicability to the course scheduling problem. Section four discusses the experimental results. In the last section we present a conclusion and recommendation for future work.

2. HARD - AND SOFT CONSTRAINED COURSE SCHEDULLING PROBLEM

2.1. Problem Definition

The course scheduling problem can be described as follows:

- there are a number of rooms ($r_1, r_2, \ldots r_r$) each of which has a seat capacity and equips a specific feature,
- a set of courses ($c_1, c_2, \ldots c_c$) each of which is attended by a certain number of student, taught by a certain lecturer and need a specific feature,

- a set of lecturer (l_1, l_2, ... l_l) each of which teaches one or more courses and has a certain time availability,
- a set of time-slot which represented by day (d_1, d_2, ... d_d) and hour (h_1, h_2, ...h_h)
- a set of events (i.e. classes), to be scheduled in a certain number of time-slots and a room, is defined as combination of a specific course with assigned lecturer attended by certain number of student from a particular group (i.e. a student group come from a specific program and same grade).

The scheduling model is represented by a three dimensional matrix (as shown in Fig. 1) where a row corresponds to day, a column corresponds to hour, and the third dimension corresponds to room. A matrix element contains a particular event (class) if it is allocated or blank if not used.

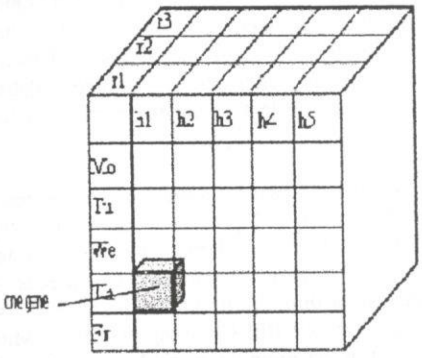


Figure 1. A three dimensional scheduling model represents one chromosome

Using evolutionary terminology, one course schedule matrix represents a chromosome in which genes are represented by the allocated events or classes.

2.2. Hard and Soft Constraints

A feasible course schedule is defined as a course schedule where all of the events/classes have been assigned into a time-slot and a room whereby the following hard constraints (HC) are fully satisfied:

- rooms must not be double booked for classes at any feasible time-slot (no-clashed classroom)
- the room capacity must not be exceeded by the number of attending student
- the room has a feature (i.e. laboratory) required by the classification
- a lecturer cannot teach more than one class at the same time
- a lecturer cannot teach any class in time-slot which is unavailable for him/her
- a student group from the same program and same grade cannot attend more than one class at the same time
- a class with multiple section must be assigned in the same room contiguously.

The first hard constraint, i.e. no-clashed classroom, is incorporated by schedule model, since one gene can only occupy one feasible room- and time-slot. The last hard constraints, i.e. continuously assigned multiple class, will be taken into account in the mutation-like mechanism of evolutionary algorithm as discussed in our previous publications [7].

While a feasible solution could be used as a valid course schedule, an optimum solution is preferred because it fulfills also some extra desired conditions on top of the just previously mentioned hard constraints. In addition, an optimum solution, that is called "nice" solution in [4], satisfies soft constraints which are demanding condition although not necessarily must be obeyed. Some examples of these soft constraints (SC) are as follows:

- a lecturer should be assigned in his/her preference time-slot
- a classroom should not be half empty, i.e. the number of attending student less than a half of room capacity
- no student should be scheduled to sit more than three events on the same day
- minimize scheduled events in the last time-slot of a day
- morning class-hours are preferred than afternoon class-hours
- minimize unoccupied room between two occupied time-slots

3. A THREE STAGE ALGORITHM FOR SOLVING TWO TYPES CONTRAINED PROBLEM

3.1. A Three Stage Approach

Lewis and Paechter have pointed out in [4][5] that two stages strategy outperforms algorithms which address both HC and SC simultaneously in single stage. In [5], Lewis and Paechter designed a *grouping genetic algorithm* (GGA) for constructing feasible schedules, and noted that their GGA is not suitable to deal with soft constraints [4]. In both publications, there are no results referring to optimum solution.

Massodian and Esteki in [3] have shown feasible- and (nearly) optimum solution using two stage algorithm constructing of genetic algorithm (GA) and local search. Both algorithms were used in each stage, because local search was actually added in GA to speed up the calculation. Hence they called it a hybrid algorithm.

Frausto-Solis and Alonso [6] have also used hybrid algorithm, namely modified simulated annealing and tabu search in two stages approach. Likes Massodian, Frausto-Solis invoked initially modified simulated annealing in attempt to obtain feasible solution, but when it failed tabu search method was used. In the second phase the same strategy was used to reach a solution as close to the optimum solution as possible.

Neither Massodian [3] nor Frausto-Solis [6] have discussed the extent of soft constraint satisfaction. Furthermore, Massoodian suppressed the essence of SC by letting the weight factor of 1% to SC in order to avoid loss of feasible solution.

In the present work we introduce a three stage, where in the first stage, an attempt to gain the optimum solution where both constraints (HC and SC) simultaneously are considered. When a feasible solution was nearly found i.e. almost all HC were fulfilled, and usually incorporated with a quite high quality of soft constraint satisfaction, the second stage will be started by focusing on searching completely feasible solution. Evolutionary algorithms are invoked in both stages with different fitness function corresponding to HC and SC as will be described later. Starting from the feasible solution of the second stage, then in the last stage using local search we attempt to minimize violations of soft constraints while keeping the number of hard constraint violations zero.

3.2. Evolutionary algorithm and modified Hill-Climbing method

The advantage using these two algorithms in the three stages approach is that both methods share same model (chromosome) and mutation mechanisms [7, 8]. The main differences between these two are found in the reproduction and selection mechanism. While EA is based on population of chromosomes at every generation [7], MHC is based on a single individual at each generation [8]. In the selection phase, a commonly used roulette wheel selection is invoked for EA. On the other hand the selection technique used in MHC deviates from common Hill Climbing method, namely instead of taking the maximum solution from all possible solution in the local neighborhood, it takes a maximum from scattered possible solutions around the current state [8].

In our previous works [7], the evolutionary algorithm (EA) has been used for constructing feasible schedules. In contrary to GGA [4, 5], using EA gives a possibility to consider both hard- and soft constraints in the same time, e.g. through the use of weight factor in the evaluation function as follow.

$$f(S) = \Sigma f_{HC}(S) + w_{SC}\ \Sigma f_{SC}(S) \quad (1)$$

where S is the solution state, $f_{HC}(S)$ and $f_{SC}(S)$ are fitness function considering hard- and soft constraint respectively and w_{SC} (in percent) is a weight factor for contribution of SC.
In the first stage, we let w_{SC} slightly less than 100% to maintain the essence of soft constraint in the solution. When the HC component of fitness value $\Sigma f_{HC}(S)$ had reached certain threshold value (say 90% of maximum possible value), w_{SC} is set to zero to find the feasible solution thoroughly.

A local search method, i.e. a modified Hill-Climbing method (MHC) will solve the soft constraint sub-problem in the last stage. In the previously published works [7,8] we had compared these two algorithms (EA and MHC) to seek the feasible course schedule. Both schedules have strength and weakness. While the Hill Climbing local search can find the solution very fast but it comes to dead-end very often [8], evolutionary algorithm generally need more time to find the solution, but when the probabilistic parameters were wisely chosen, this algorithm can always find the feasible schedule [7]. The choice of these two algorithms incorporated in the proposed three stages approaches, is based on the justification of these strength and weakness respectively. This is in-line with what Lewis and Paechter wrote in [5], i.e. "what may be a good approach for finding feasibility may not necessarily be good for optimizing soft constraints".

4. RESULTS AND DISCUSSIONS

To evaluate the proposed three stage approach, we will use a relatively small test set of 75 classes (179 course hours) to be scheduled in 4 rooms (192 hour available time-slots). For this purpose, 5 hard constraints and only 1 soft constraint are taken into account. Each constraint is set a value of 100, hence maximum f_{HC} = 500 and maximum f_{SC} = 100.Using the same set and the same constraints, we have tested three different strategies, namely a one step approach, a two stage approach and the proposed three stage approach Typical results from the tests are shown in Fig. 2, Fig. 3 and Fig. 4. These figures depict how fitness values corresponding to hard- and soft constraints vary during the evolution.

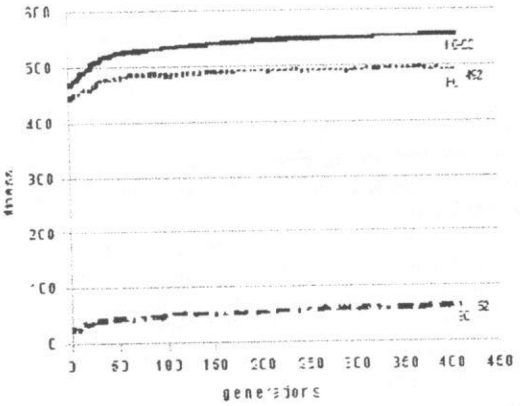


Figure 2. Typical fitness function (HC+SC, HC,SC) using one stage approach

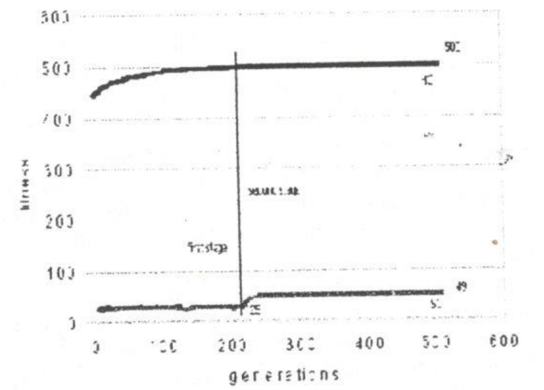
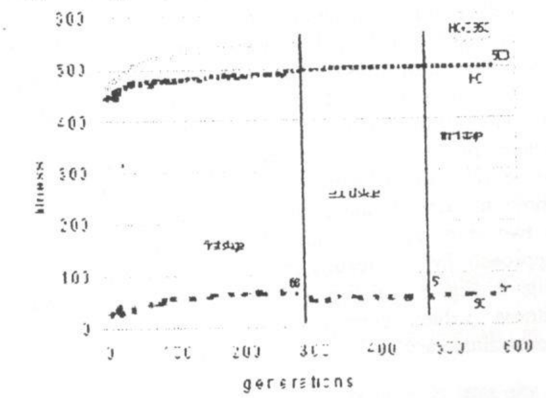


Figure 3. Typical fitness function (HC ad SC) using two stage approach

Figure 4. Typical fitness function (HC+0.9SC, HC and SC)



using three stage approach

In Fig. 1 a maximum fitness values are denoted, in this case, 492 and 62, respectively corresponding to HC and SC. When we let the evolution process further generate, highly probably the HC fitness value will not reach the maximum value of 500 because the objective function is also subjected to SC component. Hence, it is very difficult to eliminate all possible violation of hard constraints using one stage approach. The test results have shown that only 2% of possible violation cannot be vanished, nevertheless it means a non-feasible solution.

Using a two stage approach, the evolutionary algorithm in the first stage yields more satisfactory results in searching feasible solution [7], as indicated in Fig. 2 the maximum value f_{HC} = 500 reached at the end of first stage. Fig. 2 has also clearly shown transition into second stage by rapid increasing of fitness value for soft constrain. This fast growing of fitness for SC is lend from the used method hill-climbing as discussed in [7,8].

Comparing these test results of two different approaches, i.e. one stage against two stage approaches, confirms the opinion of Lewis and Paechter that two stages strategy outperforms the single stage algorithms. [4,5]. However, noted that Lewis and other researchers using two stage algorithms [3,6] did not address to quality of soft constraint fulfillment.

Our test series have indicated that the single stage approach results in better quality of SC about 10%, while it yields only less than 2% of violation in HC. This motivates us to take the benefit of both algorithms by combining those two, where the single stage as the first stage, and put the two stage strategy as the second and the third stage.

The typical result of new strategy is shown in Fig. 4. The first stage is characterized by quite steady increasing fitness for both HC and SC. Then the second stage is started when f_{HC} is close enough to maximum value, indicated in Fig. 4 by slight decreasing fitness value for SC. Finally, in the last stage, the SC fitness gains a significant increment though, no rapid fitness increasing depicted as in the two stage strategy.

5. CONCLUSIONS

We have presented a new three stage strategy to solve the hard and soft constrained course scheduling problem. The proposed strategy takes the strength of two known approaches, namely the single stage and the two stage approach, and by combining these two approaches, the weakness of both approaches are diminished. .

Two different algorithms used within the three stage approach, namely evolutionary algorithm and local search based hill-climbing which has been modified in the previous research. The evolutionary algorithm which has a strong exploring power [7] is used to ensure a feasibility solution could be found while keeping as much as possible soft constraint satisfaction in the initial two stages. The modified hill-climbing method which has a fast exploitation technique [8] is applied to invoke soft constraint satisfaction in the final stage.

For future work, we aim to speed up the computation process of both algorithm, especially in evolution mechanism and fitness evaluation by introducing parallel computing with aid of General purpose Graphic Processing Unit (GPGPU).

6. ACKNOWLEDGEMENT

The presented paper is a part of research which is supported by LP5M University Al-Azhar Indonesia through a research grant.

REFERENCES

[1] M.A. Al-Betar, A.T. Khader and T.A. Gani "A Harmony search algorithm for university course timetabling". *The Proceedings of the 7th International Conference on the Practice and Theory of Automated Timetabling,* PATAT 2008, Edmund K Burke and Michel Gendreau (eds), Montréal, Canada, 2008.

[2] E.K. Burke, D.G. Elliman and R.F. Weare, "A genetic algorithm based university timetabling system", *Proceedings of the 2nd East-West International Conference on Computer Technologies in Education*, Crimea, Ukraine, Sept, 1994, pp. 35-40

[3] S. Massoodian and A. Esteki, "A hybrid genetic algorithm for curriculum based course timetabling", *Proceeding of the 7th International Conference on the Practice and Theory of Automated Timetabling,* PATAT 2008, Edmund K Burke and Michel Gendreau (eds), August 2008

[4] R. Lewis and B. Paechter, "An empirical analysis of the grouping genetic algorithm: the timetabling case", *Proceedings of the IEEE Congress on Evolutionary Computation,* CEC 2005, 2-4 September 2005, pp.2856-2863

[5] R. Lewis and B. Paechter, "Application of the grouping genetic algorithm to university course timetabling", *Evolutionary Computation in Combinatorial Optimization*, G. Raidl and J. Gottlieb (eds), Berlin Germany, Springer LNCS 3448, 2005, pp. 144-153

[6] J. Frausto-Solís, and F. Alonso-Pecina, "A Hybrid Simulated Annealing-Tabu Search Algorithm for Post Enrollment Course Timetabling", *Proceeding of the 7th International Conference on the Practice and Theory of Automated Timetabling* PATAT '08, Edmund K Burke and Michel Gendreau (eds), August 2008

[7] A. Jamal, "University Course Scheduling using the Evolutionary Algorithm", *Proceeding of 2nd International Conference on Soft Computing, Intelligent System and Information Technology,* Bali, Indonesia, July 2010, pp.81-85

[8] Jamal, "Solving University Course Scheduling Problem using Improved Hill Climbing Approach", *Proceeding of the International Joint Seminar in Engineering,* Jakarta, Indonesia, August 2008, pp. 210-214