HYBRID PARTICLE SWARM OPTIMIZATION-CONSTRAINT-BASED REASONING IN SOLVING UNIVERSITY COURSE TIMETABLING PROBLEM

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To my beloved mother and father

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ABSTRACT

Timetabling is a frequent problem in academic context such as schools, universities and colleges. Timetabling problems (TTPs) are about allocating a number of events (classes, examinations, courses, ect) into a limited number of time slots aiming towards satisfying a set of constraints. TTPs have also been described as a class of hard-to-solve constrained optimization problems of combinatorial nature. They are classified as constraints-satisfaction problems that intend to satisfy all constraints and optimize a number of desirable objectives. Various approaches have been reported in the literatures to solve TTP, such as graph coloring, heuristic, genetic algorithm and constraint logic programming. Most of these techniques generate feasible but not optimal solutions or results. Therefore, this research focuses on producing a feasible and yet good quality solution for university courses timetabling problem. In this thesis, we proposed a new hybrid approach by exploiting particle swarm optimization (PSO) and constraint-based reasoning (CBR). PSO is used to generate potential solutions to ensure that the algorithm is generic enough to avoiding local minima and problem dependency while utilizing a suitable fitness function. Meanwhile, CBR helps to satisfy constraints more effectively and efficiently by posting and propagating constraints during the process of variable instantiations. CBR procedures are applied to determine the validity and legality of the solution, followed by an appropriate search procedure to improve any infeasible solution and significantly reduce the search space. Results of this study have significantly proven that hybrid PSO-CBR has the ability to produce feasible and good quality solutions using real-world universities and benchmark datasets.

ABSTRAK

Penjadualan ialah masalah lazim yang wujud di dalam bidang akademik seperti sekolah, universiti dan kolej. Masalah penjadualan (MP) adalah untuk mengumpukkan beberapa peristiwa seperti kelas, peperiksaan, kursus dan sebagainya ke dalam beberapa slot masa bagi memenuhi satu set kekangan. MP juga digambarkan sebagai satu kelas pengoptimum masalah kekangan bersifat kombinatorik yang sukar untuk diselesaikan. Ia diklasifikasi sebagai masalah kepuasan kekangan yang bertujuan untuk memenuhi kesemua kekangan dan mengoptimumkan sebilangan objektif yang diingini. Beberapa pendekatan telah dilaporkan dalam kajian literatur untuk menyelesaikan MP seperti penggunaan teknik pewarnaan graf, heuristik, algoritma genetik dan pengaturcaraan logik kekangan. Kebanyakan teknik yang digunakan hanya dapat menjanakan hasil atau keputusan yang tersaur tetapi tidak optimum. Oleh itu, fokus kajian ini adalah menjana jadual waktu universiti yang tersaur dan berkualiti tinggi. Dalam tesis ini, satu pendekatan hibrid yang baru dicadangkan menggunakan teknik pengoptimuman partikel berkelompok (PSO) dan pendekatan taakulan berasaskan kes (CBR). PSO digunakan untuk menjana penyelesaian berpotensi bagi memastikan algoritma yang dihasilkan adalah generik, dapat menyelesaikan masalah minima tempatan dan masalah kebergantungan disamping menggunakan fungsi muatan yang bersesuaian. Sementara itu, CBR digunakan untuk memuaskan kekangan dengan lebih efektif dan berkesan dengan menghantar dan menyebar kekangan semasa proses menilai awal pembolehubah. Prosidur CBR juga diaplikasikan bagi menentukan kepatuhan dan kesahan penyelesaian, diikuti dengan prosidur carian yang sesuai untuk memperbaiki penyelesaian yang tidak tersaur dan secara jelas dapat mengurangkan ruang carian. Keputusan kajian ini telah membuktikan secara jelas bahawa algoritma hibrid PSO-CBR mempunyai kemampuan untuk menghasilkan penyelesaian yang tersaur dan berkualiti tinggi menggunakan data sebenar universiti dan data setara.

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LIST OF ABBREVIATIONS

TTP	-	Timetabling Problem
UCTP	-	University Course Timetable Problem
ETP	-	Exam Timetabling Problem
PSO	-	Particle Swarm Optimization
CBR	-	Constraint-based Reasoning
TS	-	Tabu Search
GA	-	Genetic Algorithms
GHH	-	Graph-based Hyper-Heuristic
MO	-	Multi-Objective
ACS	-	Ant Colony System
WoSP	-	Waves of Swarm Particles
LS	-	Local Search
RAP	-	Resource Allocation Problem
CSP	-	Constraint-Satisfaction Problems
LCV	-	Least Constraining Value
GV	-	Greedy Value

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CHAPTER I

INTRODUCTION

1.0 Overview

Timetabling can be considered as a type of scheduling problem. Scheduling is the allocation, subject to constraints, of resources to objects being placed in space-time, in such a way as to minimize the total cost of some set of the resources used; whilst timetabling is a problem that usually arises in most common type of academic context such as schools, universities and colleges (Muller, 2005). Scheduling often aims to minimize the total cost of resources used, whilst timetabling often tries to achieve the desirable objectives as much as possible. It has also been pointed out that timetabling decides upon the time when events will take place, but does not usually involve the allocation of resources in the way that scheduling does (Petrovic and Burke, 2004). The process of generating a university course timetable for instance does not usually involve in specifying which lecturers will be allocated to which particular subject. Normally, this information will be decided after the timetable is actually constructed. The constructions of subject's allocation are common problem for all institutions of higher education.

The main task of timetabling problem (TTP) is to allocate a number of events (courses, classes, exams, lessons) into a limited number of resources (classrooms) and periods (timeslots) with the aim to satisfy a set of stated objectives to the highest possible extent (Petrovic and Burke, 2004). The TTPs normally arises in a wide variety of domains including educational timetabling problem (i.e. university and school timetabling), transport timetabling problem (i.e. train and bus timetabling), healthcare institutions timetabling problem (i.e. surgeon and nurse timetabling) and sport timetabling problem (i.e. timetabling of matches between pairs of team). The most common variants of educational timetabling problem are the university course timetable problem (UCTP) and Exam Timetabling Problem (ETP). Both of it have quite similar constraints. A slight difference between them is ETP events can take place in the same classroom and timeslot as long as the desire constraints are satisfied, while in UCTP, only one event can take place in a desired classroom at a selected timeslot. This research focuses in solving UCTP.

In this chapter, the basic concepts and backgrounds of timetabling problems will be discussed. Besides, the problem statements, goals and objectives, and the significant of the research will be presented in the following sections of this chapter.

1.1 Background of the Problem

Every year or term in a university, each individual department has to design a new timetable for subjects or exams. The TTP can be considered as a scheduling problem that consists in fixing a sequence of meeting between lecturers and students in a prefixed period of time (typically a week), satisfying a set of constraints of various types. Among the wide variety of TTPs, educational timetabling is one of the mostly studied from a practical viewpoint (Qu et al., 2006). Educational timetabling is one of the most important and time-consuming tasks which occur periodically (i.e. annually, etc) in all academic institutions. It is known as NP-complete problem (Deris et al., 2000) because it is a difficult problem with a lot of constraints to be solved and a huge search space to be explored if the problem size increases (Ozcan and Ersoy, 2005; Mahdi et al., 2003; Sigl et al., 2003; Fu et al., 2000; Deris et al., 2000). The educational timetabling problems are divided into two types: the UCTP and ETP. This research focuses on optimizing the UCTP (curriculum based scheduling) and maximizing the usage of classrooms and timeslots with minimum error. The UCTP have been further specialized in either post enrollment based or curriculum based. In post enrollment problems, the timetable must be constructed in such a way that all students can attend the events on which they are enrolled, whereas in curriculum problems the constraints are defined according to the university curricula and not based on enrollment data (Bratkovic et al., 2009).

UCTP is basically the scheduling and assignment of the events (subjects) to a number of rooms (resources) and timeslots (periods) respectively, without causing time clashes for the students, as well as the resource clashes (Srinivasan et al., 2002). The construction of course timetables for universities is a very difficult problem with a lot of constraints that have be satisfied under an exploration of a huge search space, even though the size of the problem is not significantly large, due to the exponential number of the possible feasible timetables. The UCTP itself does not have a widely approved definition, since different variations of it are faced by different universities. This problem therefore is proven to be a very complex and time-consuming task. Many of the solutions generated by other researchers provide feasible solution (Tuncay, 2007; Sigl et al., 2003; Adora et al., 2002; Chu and Fang, 1999; Burke et al., 1993; de Werra, 1985). A feasible solution is a solution that satisfies all the hard constraints under any circumstances. Hard constraints are constraints that must be satisfied simultaneously while soft constraints are those that to be fulfilled if possible. The quality of a feasible solution can be judged on how well the soft constraints are satisfied. If an objective function is given, an optimal solution can be found by satisfying all the constraints (hard and soft) (Deris et al., 1999).

This research is aimed at producing a feasible and good quality timetable with all the hard constraints are satisfied; whilst optimizing the soft constraints utilizing the strength of PSO to search potential solution for TTP and CBR to validate the optimized solution generated by PSO, and if violation occurred a backtracking strategy will be applied.

1.2 Statement of the Problem

The main research question under these UCTPs is:

"Could hybrid PSO-CBR algorithms produce a feasible and better quality timetable for UCTPs?"

Thus, the following issues will arise to answer the main research question stated above:

- How to model UCTPs in flexible and complex educational environment?
- Which part of the two algorithms will be hybrid in order to solve the UCTPs?
- How to model the hybrid PSO-CBR algorithms with UCTP?
- How to integrate the hybrid PSO-CBR algorithms with all the constraints?
- How to measure the feasibility and quality of the generated timetable?

- What is the fitness function to be utilized to produce feasible and better quality timetable?

The hypothesis of this study can be stated as:

"By hybridizing PSO-CBR, it can lead to a better performance into providing a feasible and better quality solution with a minimal computational time"

1.3 Goal and Objectives of the Study

The ultimate goal of this research is to develop a hybrid algorithm of PSO-CBR in order to find a feasible and better quality timetable solution that satisfies all the constraints with minimal computational time; It is expected to achieve objectives as follow:-

- To propose and explore Hybrid PSO-CBR Algorithm in Solving UCTPs.

- To model and develop the Hybrid PSO-CBR Algorithm for UCTPs.

- To validate the performance of the proposed approach against standard PSO, hybrid PSO-local search and hybrid genetic algorithm-CBR using real UCTP data.

1.4 Scope of the Study

The scopes of this study are as follows:

- Data used is collected from Faculty of Computer Science & Information System, University of Technology Malaysia for semester I 2008/2009 (curriculum based TTP).

- This research will concentrate on solving the UCTPs to reach the better quality and feasible solution.

- This research does not consider into making changes (changes from human factors required) after a timetable solution is produced.

- This study will focus on offline running algorithm (stand alone) rather than online running algorithm (web page).

1.5 Significance of the Study

This study is expected to produce a hybrid PSO-CBR algorithm by which it will be able to deal with the UCTPs, a NP-Complete problem (Deris et al., 2000; Azimi et al., 2005). In fact, through the literature review studies, this hybrid approach has never been tried on any timetabling problem. Therefore, the challenges of this research are to produce a good quality timetable and adapt the timetabling problems into the proposed approach. Thus, at the end of this research, we believe that the proposed algorithm can provide an efficient and better quality solution that fulfills all the constraints. With the co-operation of chosen fitness function, the utilization of good classrooms and timeslots will be maximized. This algorithm is believed to be very useful not only for UCTP, but also in manufacturing scheduling, staff scheduling, maintenance scheduling and so forth.

1.6 Thesis Outline

A general description of the contents of subsequent chapters in this thesis is given as follows:

- Chapter 2 defines and reviews the timetabling problem and university course timetabling problem characteristic. It also describes the theory related to proposed approach.

- Chapter 3 gives the overall methodology adopted to achieve the objectives of this research.

- Chapter 4 elaborates the modeling process of generating feasible and better quality university timetable solution.

- Chapter 5 explains the model implementation for university course timetable problem and results by using proposed algorithm are discussed together with validation of proposed algorithm with other approaches.

- Chapter 6 concludes the thesis and some suggestions for future research is provided.

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