UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TASKS DISTRIBUTION IN DRIVER SCHEDULING USING DYNAMIC SET OF BANDWIDTH IN HARMONY SEARCH ALGORITHM WITH 2-OPT

ZATUL ALWANI BINTI SHAFFIEI

DOCTOR OF PHILOSOPHY

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A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy

Faculty of Information and Communication Technology

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2021

DECLARATION

I declare that this thesis entitled "Tasks Distribution in Driver Scheduling using Dynamic Set of Bandwidth in Harmony Search Algorithm with 2-Opt" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	……………………………………
Name	:	Zatul Alwani binti Shaffiei
Date	:	……………………………………

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature	:	………………………………………………
Supervisor Name	:	Assoc. Prof. Ts. Dr. Zuraida binti Abal Abas
Date	:	………………………………………………

DEDICATION

To my late mother, Tengku Rofiah binti Tengku Zainal

Always miss you, every day!

ABSTRACT

Scheduling is important when dealing with task distributions and time management. In most organisations, the scheduling process is still generated manually. It consumes a lot of time and energy; consequently, the generated schedule is not really efficient. One of the main issues in scheduling is unfair tasks distribution among drivers. A fair schedule is necessary since it determines the quality of service as well as staff or customer satisfaction. Basically, a fair schedule can be defined as a well-balanced distribution of tasks among machines or staff by satisfying most of their constraints and personal preferences. There are two types of constraint to be considered in scheduling, which are hard constraint and soft constraint. This research was focused on driver scheduling problem for university shuttle bus (DSPUSB). Based on previous research using one of metaheuristic algorithms known as harmony search (HS), the generated schedule was still not optimum and cannot be solved maximally as there were too much repetitions of task (shift and route) occurred among drivers. The existing techniques (HS and its variants) have issues in terms of searching strategy (exploration and exploitation), slow convergence rate and high computation time for solving the scheduling problems maximally or near to optimal one. Therefore, a tasks distribution in driver scheduling using dynamic set of bandwidth in harmony search algorithm with 2-opt (SBHS2-opt) was proposed in this research. In the standard HS, the value of bandwidth (BW) parameter was static, while in this research, a dynamic set of bandwidth (BW2) value was formed based on constraints (problem domain). The BW2 value was dynamically changed and determined based on the current solution (with heuristic concept) of each driver every week, whereas the 2-opt swapping, which is normally used in travelling salesman problem, was applied for route constraint based on specific rules. The SBHS2-opt has guided searching strategy using heuristic concept or known as informed search. Knowledge on the problem is needed to assist the searching process and to strengthen the exploitation. There were 33 experiments carried out with different numbers of driver, route and shift. The results produced by SBHS2-opt outperformed 31 experiments out of 33 experiments. Hence, it was clearly shown that these improvements were capable in strengthen the exploitation, increase convergence rate, low computation time and at the same time balance the tasks distribution among drivers. In addition, the statistical analysis using Wilcoxon Rank-Sum Test and Bonferroni-Holm Correction as well as Box–Whisker plotting demonstrated that the SBHS2-opt has a significant difference in most of the experiments and was more stable in searching the best solution compared to HS, improved HS, parameter adaptive HS and step function HS.

PEMBAHAGIAN TUGAS DALAM PENJADUALAN PEMANDU MENGGUNAKAN SET JALUR LEBAR DINAMIK DALAM ALGORITMA PENCARIAN HARMONI DENGAN 2-OPT

ABSTRAK

Penjadualan adalah penting apabila berurusan dengan pembahagian tugas dan pengurusan masa. Dalam kebanyakan organisasi, proses penjadualan masih dihasilkan jadual secara manual. Ianya memakan banyak masa dan tenaga; akibatnya, jadual yang dihasilkan kurang berkesan. Isu utama dalam penjadualan adalah ketidakadilan pembahagian tugas dalam kalangan pemandu. Jadual yang adil perlu kerana ia menentukan kualiti servis dan kepuasan pekerja atau pelanggan. Secara asasnya, jadual yang adil didefinisikan sebagai pembahagian tugas yang seimbang dalam kalangan pekerja atau mesin dengan memenuhi kebanyakan kekangan dan keutamaan peribadi. Terdapat dua jenis kekangan yang perlu dipertimbangkan dalam penjadualan iaitu; kekangan wajib dan kekangan harus. Kajian ini fokus kepada masalah penjadualan pemandu bagi bas ulang alik universiti (DSPUSB). Berdasarkan kajian terdahulu menggunakan salah satu algoritma metaheuristik iaitu pencarian harmoni (HS), jadual yang dihasilkan masih tidak optimum dan tidak dapat diselesaikan secara maksimal kerana terdapat banyak pengulangan tugas (syif dan laluan) yang berlaku dalam kalangan pemandu. Teknik-teknik sedia ada (HS dan variasinya) mempunyai isu-isu dari segi strategi pencarian (eksplorasi dan eksploitasi), kadar penumpuan yang perlahan dan masa komputasi yang tinggi untuk menyelesaikan masalah penjadualan secara maksimal atau dekat dengan optimum. Oleh itu, pembahagian tugas dalam penjadualan pemandu menggunakan set jalur lebar dinamik dalam algoritma pencarian harmoni dengan "2-opt" (SBHS2-opt) telah dicadangkan dalam kajian ini. Dalam HS yang asas, nilai parameter jalur lebar (BW) adalah statik, manakala dalam kajian ini; satu set jalur lebar dinamik (BW2) dibentuk berdasarkan kekangan (masalah domain). Nilai BW2 berubah secara dinamik dan ditentukan berdasarkan penyelesaian semasa (dengan konsep heuristik) setiap pemandu pada setiap minggu manakala penukaran "2-opt" yang biasa digunakan dalam masalah perjalanan jurujual telah digunakan untuk kekangan laluan berdasarkan peraturan khusus. SBHS2-opt mempunyai strategi pencarian berpandu yang menggunakan konsep heuristik atau lebih dikenali sebagai pencarian maklum. Pengetahuan tentang masalah diperlukan untuk membantu proses pencarian dan untuk memperkukuhkan eksploitasi. Terdapat 33 eksperimen yang telah dijalankan dengan bilangan pemandu, laluan dan syif yang berbeza. Keputusan yang dihasilkan oleh SBHS2-opt telah mengatasi 31 eksperimen daripada 33 eksperimen. Oleh itu, ianya jelas menunjukkan bahawa penambahbaikan ini mampu mengurangkan, memperkukuhkan eksploitasi, meningkatkan kadar penumpuan, masa komputasi yang rendah dan sekaligus seimbangkan pembahagian tugas dalam kalangan pemandu. Sebagai tambahan, analisis statistik menggunakan kaedah "Wilcoxon Rank-Sum" dan pembetulan "Bonferroni-Holm"; serta plot "Box-Whisker" menunjukkan bahawa SBHS2-opt mempunyai perbezaan yang signifikan dalam kebanyakan eksperimen dan juga lebih stabil dalam mencari penyelesaian terbaik berbanding dengan HS, penambahbaikan HS dan penyesuaian parameter HS.

ACKNOWLEDGEMENTS

Firstly, thanks to Allah Almighty for His greatness and for giving me the strength and courage to complete this thesis. I would like to express my sincere appreciation to my main supervisor Assoc. Prof. Ts. Dr. Zuraida binti Abal Abas for her continuous support during my Ph.D study and related research, her patience, motivation, and immense knowledge. Her guidance has helped me throughout my research and the writing of this thesis. I would also like to give my biggest appreciation and a very special thanks to my beloved husband, Amir Syafiq Syamin Syah bin Amir Hamzah, my father, Shaffiei bin Mohd and my parents in law, Amir Hamzah bin Nordin and Hamidah binti Hassan for their endless love, quality time, help, pray, understanding and continuous support. In addition, I would like to express my profound gratitude to my co-supervisor Dr. Norhazwani binti Md Yunos, and my ex co-supervisor Assoc. Prof. Dr. Abdul Samad bin Shibghatullah for their support and assistance in strengthening my knowledge in this field. Besides that, I would also like to thank the Ministry of Higher Education Malaysia (MOHE) for the financial support throughout my study, under MyPhD MyBrain15 scheme. Not to be forgotten, thanks to all my siblings and my siblings in law for being the best support system. Special thank goes to my fellow lab mates and friends, who always gave me precious suggestions, opinions and comments related to my research. Lastly, I want to express my appreciation and thanks to all lecturers, laboratory technicians, and all administrative staffs of Faculty of Information and Communication Technology for their assistance and support.

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LIST OF ABBREVIATIONS

BW	:	Bandwidth
BW2	:	Dynamic Set of Bandwidth
CSAHS2-opt		Constrained Self-Adaptive Harmony Search Algorithm with 2-opt Swapping
DSP	:	Driver Scheduling Problem
DSPUSB	:	Driver Scheduling Problem for University Shuttle Bus
GHS	:	Global Best Harmony Search
HM	:	Harmony Memory
HMCR	:	Harmony Memory Consideration Rate
HMS	:	Harmony Memory Size
HS	:	Harmony Search
IHS	:	Improved Harmony Search
PAHS	:	Parameter Adaptive Harmony Search
PAR	:	Pitch Adjustment Rate
SAHS	:	Self-Adaptive Harmony Search

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Scheduling is very important when dealing with task distributions and time management in any organizations. There are many fields that required scheduling such as transportation (bus, train and flight scheduling) (Limlawan et al., 2011; Yaghini et al., 2015; Constantino et al., 2017), medical field (nurse scheduling) (Glass and Knight, 2010; Ramli et al., 2016a), manufacturing (machine scheduling) (Zamli, 2014; Che et al., 2016), and education (course and examination scheduling) (Babaei et al., 2014; Larabi Marie-Sainte, 2015). Without a schedule, the task distribution among the staffs and machines will be chaotic.

Generally, scheduling is the process of arranging, controlling and assigning tasks or workloads to machines or staffs (crews) based on some constraints. Normally, in most scheduling problem, constraints are divided into two types which are; hard constraint and soft constraint (Shaffiei et al., 2016, 2018). Hard constraint is a constraint that is compulsory to be fulfilled in order to make sure a feasible schedule can be produced (Cheang et al., 2003; Pillay and Banzhaf, 2010; Ramli et al., 2013a; Yaghini et al., 2015). A feasible schedule is an initial schedule that can be applied to machines or staffs but it is not good enough since the soft constraint is not taking into account. Soft constraint is a constraint that is not necessary to be fulfilled, but, by minimizing the violation of this constraint, an optimum schedule can be generated (Al-Betar et al., 2012; Belén et al., 2012; Hadwan et al., 2013; Anwar et al., 2014).

In some papers, there is another type of constraint to be solved named, precedence or priority constraint. The precedence constraint can be defined as a dependent constraint; where the next task cannot be executed if the previous task which is included in precedence constraint still not been accomplished. This type of constraint typically illustrated in acyclic directed graph (Skutella and Uetz, 2005; Widmer et al., 2010; Brucker et al., 2011). Apart from that, the personal preference also been considered in solving scheduling problem. Personal preference is referring to a self-requirement or request, it is not compulsory to be satisfied, for examples, in a nurse scheduling, a nurse requests to off-duty during first weekend; in a train driver scheduling, a driver requests to work overtime on every Thursday. If these examples of preferences were fulfilled, it will give a high satisfaction to that nurse and driver, though, a schedule still can be used if their preferences were violated (Legrain et al., 2015; Muramudalige and Bandara, 2018; Pillay and Qu, 2018). Constraints or preferences might be varies among countries and institutions (Ahmad, 2015).

In fact, scheduling process is quite complex and complicated to be solved especially if it is done manually and involving the large number of machines, tasks or staffs. However, in most organizations, the scheduling process is still generated manually. It is consuming time, energy and resources; consequently, a generated schedule is not really efficient. One of the main issues in scheduling is fairness. Basically, fairness can be defined as a well-balanced distribution of tasks among machines or staffs by satisfying most of their constraints and personal preferences. It is almost impossible to achieve a perfect schedule with a well-balanced distribution of tasks. A feasible schedule does not have to be fair enough since only hard constraints are fulfilled. Therefore, the soft constraints or personal preferences are preferred to be satisfied to guarantee a fair schedule. Fairness in a schedule is absolutely necessary since it determines the quality of service or performance and staffs' or customers' satisfaction.

1.2 Research background

The scheduling of drivers is needed especially for public transport such as express buses, taxi, flight and train. It is a worldwide problem. Driver scheduling problem (DSP) that can be classified into NP-hard problems (Lenstra and Rinnooy Kan, 1981; Li, 2005) is one of the complex problems in transportation field. Basically, it can be defined as the process of distributing tasks or duties to drivers based on vehicle schedule within particular period, typically a week or a month (Belén et al., 2012). In some papers, the driver scheduling also referred as a crew scheduling as in (Limlawan et al., 2011; Ulrich, 2015; Kasirzadeh et al., 2017). According to Belen et al. (2012), usually in driver scheduling process, there are two phases involved which are staffing phase; estimation of the number of drivers needed to cover the needs of working hours, and scheduling phase; development of calendars of work to cover the estimation of drivers acquired in the phase of the staffing (Belén et al., 2012).

The vehicle scheduling and driver scheduling are closely related. In planning the vehicle scheduling, the driver scheduling or also known as crew scheduling should be emphasized to carry out the duties, tasks or shift based on the vehicle schedule that has been provided. Some researchers solved both schedules using sequential approach which is solving the vehicle schedule first, followed by driver schedule (Oughalime et al., 2009). Based on vehicle schedule, for example, a flight has to return from Kuala Lumpur to Jakarta three times in a day (vehicle schedule). To carry out this task, a few pilots should be assigned to the vehicle schedule (driver or crew schedule). Zhao in (Zhao, 2006) stated that, it is necessary to assign shift and duties to drivers, so that every bus (or any vehicle) has a driver at all times.

Normally, the number of driver assigned for vehicle schedule is based on passengers' demand. The route with higher demand or the route that is more popular such as in a main city will be assigned with larger number of drivers. This is to ensure that the vehicle schedule can be covered. For example, an express bus from Melaka to Kuala Lumpur needs 8 trips in a day, while from Melaka to Shah Alam needs 3 trips in a day. This is because of the route of Melaka to Kuala Lumpur has higher demand by passengers and more popular since Kuala Lumpur is a main city compared to the route of Melaka to Shah Alam. Therefore, the number of driver assigned to the route of Melaka to Kuala Lumpur is larger than the number of driver assigned to the route of Melaka to Shah Alam.

As a matter of facts, problems that always been focused by researchers in DSP are the drivers' wages (Chen and Li, 2010), number of working days, shift (working hours and overtime), route (multiple depot) and break time assignment (Ramli et al., 2013b). It must be noted that these problems are related to fairness issue. They are very crucial to be solved in an optimum way since it will affect the quality of service and customers' satisfaction. In worse situation, the drivers that working non-stop, overtime and more than fixed working hours can lead to fatigue and consequently can cause an accident as reported in (Goel et al., 2012; Bowden and Ragsdale, 2018). Based on some news reported, mostly, this case happened for truck and express bus that involves with the long journey.

Unlike in most universities, shuttle bus services are provided for students to facilitate students in attending the classes, lectures, co-curricular activities or any activities held in their campus. Thus, the driver scheduling is needed to ensure that the duties or tasks are