UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ENHANCING HARMONY SEARCH PARAMETERS BASED ON STEP AND LINEAR FUNCTION FOR BUS DRIVER SCHEDULING AND ROSTERING PROBLEMS

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A thesis submitted

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DECLARATION

I declare that this thesis entitle “Enhancing Harmony Search Parameters based on Step and Linear Function for Bus Driver Scheduling and Rostering Problems” 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 : Nur Farraliza Binti Mansor

Date :

APPROVAL

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

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Signature	:	
Name	:	Assc. Prof. Dr. Zuraida Binti Abal Abas
Date	:	

DEDICATION

I dedicate this work to my mother, Faridah binti Taib, my father, Mansor bin Kassim, and my siblings Mastura, Syaiful Azreen, Muhammad Hafizuddin and Siti Nurhayah who supported me all the way and whose encouragement made sure that I gave all it takes to finish that which I have started. I am truly thankful for having you in my life. My love for you all can never be quantified. May Allah bless you with his ultimate Mercy.

ABSTRACT

Optimization is a major challenge in numerous practical world problems. According to the "No Free Lunch (NFL)" theorem, there is no existing single optimizer algorithm that is able to resolve all issues in an effective and efficient manner. It is varied and need to be solved according to the specific capabilities inherent to certain algorithms making it hard to foresee the algorithm that is best suited for each problem. As a result, the heuristic technique is adopted for this research as it has been identified as a potentially suitable algorithm. Alternative heuristic algorithms are also suggested to obtain optimal solutions with reasonable computational effort. However, the heuristic approach failed to produce a solution that nears optimum when the complexity of a problem increases; therefore a type of nature-inspired algorithm known as meta-heuristics which utilises an intelligent searching mechanism over a population is considered and consequently used. The meta-heuristic approach is widely used to substitute heuristic terms and is broadly applied to address problems with regards to driver scheduling. However, this meta-heuristic technique is still unable to address the fairness issue in the scheduling and rostering problems. Hence, this research proposes a strategy to adopt an amendment of the harmony search algorithm in order to address the fairness issue which in turn will escalate the level of fairness in driver scheduling and rostering. The harmony search algorithm is classified as a meta-heuristics algorithm that is capable of solving hard and combinatorial or discrete optimisation problems. In this respect, the three main operators in harmony search, namely the Harmony Memory Consideration Rate (HMCR), Pitch Adjustment Rate (PAR) and Bandwidth (BW) play a vital role in balancing local exploitation and global exploration. These parameters influence the overall performance of the HS algorithm, and therefore it is crucial to fine-tune them. Therefore, it is of great interest that we find adjustments for these parameters in this research. There are two contributions to this research. The first one is having HMCR parameter using step function and the linear increase function while the second is applying the fret spacing concept on guitars that is associated with mathematical formulae is also applied in the BW parameter. There are three proposed models on the alteration of HMCR parameters based on the use of the fundamental step function; namely, the constant interval of step function, and its dynamic increase and decrease interval functions. The experimental results revealed that our proposed approach is superior to other state of the art harmony searches either in specific or generic cases. This is achieved by using a first type of association between the linear increase function with a second model of the dynamic increase of step function being remarkable in other combinations and also other models. In conclusion, this proposed approach managed to generate a fairer roster and was thus capable of maximising the balancing distribution of shifts and routes among drivers, which contributed to the lowering of illness, incidents, absenteeism and accidents.

ABSTRAK

Pengoptimuman merupakan cabaran dalam kebanyakan masalah praktikal yang dihadapi di seluruh dunia. Menurut teorem "No Free Lunch (NFL)", tidak terdapat satu algoritma pengoptimuman yang berkebolehan untuk menyelesaikan semua masalah dengan efektif dan efisien. Ianya bervariasi dan perlu diselesaikan berdasarkan kepada kebolehan yang terdapat pada jenis algoritma yang ingin digunakan untuk menyelesaikannya. Akibatnya, adalah sukar untuk meramal algoritma paling sesuai untuk setiap permasalahan. Oleh itu, teknik heuristik diguna pakai kerana ianya dikenalpasti sebagai salah satu algoritma yang mempunyai potensi dan berkemungkinan sesuai dengan konteks kajian ini. Walaubagaimanapun,pendekatan heuristik telah gagal menghasilkan penyelesaian mendekati keadaan optimum khususnya apabila sesuatu masalah menjadi bertambah rumit. Pendekatan meta-heuristik ini telah digunakan untuk menggantikan terma heuristik bertujuan untuk menyelesaikan masalah yang berkait dengan penyelarasan dan penjadualan kerja pemandu. Walaubagaimanapun, teknik meta-heuristik ini masih gagal menyelesaikan isu keadilan berbangkit. Oleh itu, kajian ini mengetengahkan strategi berasaskan pengubahsuaian kepada algoritma pencarian harmoni bagi menangani aspek keadilan yang dijangkakan akan meningkatkan lagi tahap keadilan dalam perihal penyelarasan dan penjadualan kerja pemandu. Algoritma pencarian harmoni dikelaskan sebagai algoritma meta – heuristik yang berkebolehan untuk menyelesaikan masalah. Ketiga-tiga pengendali utama HS iaitu Kadar Pertimbangan Ingatan Harmoni, Kadar Pelarasan Pic dan Lebar Jalur memainkan peranan penting dalam eksploitasi setempat serta penjelajahan global. Terdapat dua sumbangan utama kajian ini. Yang pertama adalah parameter Kadar Pertimbangan Ingatan Harmoni melalui kaedah fungsi langkah serta fungsi pertambahan linear, manakala sumbangan yang ke dua menggunakan konsep penjarakan fret pada gitar yang berkait rapat dengan rumus matematik digunakan pada parameter Lebar Jalur. Terdapat tiga model yang diusulkan bagi pemindaan atas parameter Kadar Pertimbangan Ingatan Harmoni berdasarkan penggunaan fungsi langkah asas iaitu menyelangkan fungsi langkah secara tetap dan juga penambahan dan pengurangan dinamik fungsi selang. Hasil ujikaji menunjukkan bahawa pendekatan yang dicadangkan dalam kajian ini adalah lebih baik daripada kaedah-kaedah pencarian harmoni terkini yang lain dalam kes khusus mahupun kes generik. Hasil tersebut telah dicapai dengan menggunakan suatu perkaitan pertama antara fungsi penambahan linear dengan model kedua penambahan dinamik fungsi langkah di mana kombinasi ini didapati merupakan yang terbaik diantara yang lain. Kesimpulannya, kaedah yang diusulkan ini telah menghasilkan jadual kerja yang lebih adil dan berkebolehan untuk memaksimumkan keseimbangan taburan syif dan laluan dikalangan pemandu bas, sekaligus mengurangkan berlakunya kes kemalangan, ketidakhadiran, insiden serta penyakit.

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LIST OF ABBREVIATIONS

DSP	:	Bus Driver Scheduling Problems
BDRP	:	Bus Driver Rostering Problems
DSRP	:	Bus Driver Scheduling Rosterin Problems
HS	:	Harmony Search
HM	:	Harmony Memory
PAR	:	Pitch Adjustment Rate
BW	:	Bandwidth
HMS	:	Harmony Memory Size
HMCR	:	Harmony Memory Consideration Rate
HSA	:	Harmony Search Algorithm
PAR	:	Pitch Adjustment Rate

LIST OF PUBLICATIONS

Proceeding

1. International Symposium on Research in Innovation and Sustainability
2. The 2nd International Conference on the Harmony Search Algorithm (ICHSA 2015)
3. IOP Conference Series: Materials Science and Engineering

Journal

1. NF Mansor, ZA Abas, AFNA Rahman, AS Shibghatullah, S Sidek, An analysis of the parameter modifications in varieties of harmony search algorithm, International Review on Computers and Software (IRECOS) 9 (10), 1736-1749
2. NF Mansor, ZA Abas, AFNA Rahman, AS Shibghatullah, S Sidek, An Optimization Solution Using A Harmony Search Algorithm, International Symposium on Research in Innovation and Sustainability, 15-16

Book Chapter

1. NF Mansor, ZA Abas, AFNA Rahman, AS Shibghatullah, S Sidek, A New HMCR Parameter of Harmony Search for Better Exploration, The 2nd International Conference on the Harmony Search Algorithm (ICHSA 2015) Advances in Intelligent Systems and Computing 382, Springer-Verlag Berlin Heidelberg 2016

CHAPTER 1

INTRODUCTION

1.1 Introduction

Optimisation is described as the accumulation of mathematical algorithms where various engineering applications are succeed. Conventional mathematical approaches cannot cope with some of the recent applications that are extremely complicated. This has led to the development of a new mechanism for new design solution in accordance with the field of general nature-inspired algorithms known as metaheuristics. This method was developed in the past years based on collective behaviour of natural or artificial decentralised self-organised systems (Dorigo and Stützle, 2004; Pham et al., 2006; Aderhold et al., 2010). The sophisticated collective intelligence tactics are exploited to be adopted in algorithms and it has been illustrated as powerful problem-solving features as asserted in the study of Bonabeau et al. (1999). It comprises an easy interaction agent that refers to intelligence rests in the networks of interaction between individuals as well as among individuals and the environment. Evolutionary or swarmed based algorithms indicate a generic population founded by metaheuristic optimisation algorithms. These metaheuristics are typically inspired on metaphors expressing natural process or social phenomena. The harmony search (HS) algorithm is among the freshest metaheuristic algorithms.

The harmony search (HS) algorithm is initiated by Geem et al. (Geem et al, 2001) in year 2001. HS algorithm is categorised as novel population according to literature survey on metaheuristics. The HS algorithm is devised from the domain of music. In its foundation or root theory of HS, the approaches inspired by the musical performance steps participate when a group of musicians hunt for a harmonious symphony and continue to polish their tune to reach an escalation pleasant harmonies. Harmonising musical harmony is corresponding to an optimisation solution, whereas in optimisation technique, improvisation of music is corresponding to the local and global searching mechanism to a problem. From this view, the aesthetic quality referring to the combination of each pitch generated by musical instruments is equivalent to the objective function value. Various variables allotted a set of values defined as an objective to a problem. As a matter of facts, the total number of publications in connection of harmony search has rapidly grown. In 2010, Google Scholar has recorded 500 searches for harmony search including the quotation mark (Weyland, 2015). The same search has showed about 3000 results in 2012, whereas by the end of 2014, the result was further increased to a number greater than 9000. Some of the areas with a highest rate of request to be put into practise of HS are power flow problem (Sivasubramani and Swarup, 2011), flow shop problem (Gao et al., 2015), water design distribution networks (Geem, 2006), truss structures optimisation (Kaveh and Talatahari, 2009), problems of orienteering (Geem et al., 2005), solving sudoku (Geem, 2007), steel sway frames design (Saka, 2009) and transportation scheduling (Mansor et al., 2016)

The HS was opted and being the focus of this research due to several remarkable advantages over other metaheuristic approaches. For instance, the HS algorithm implements stochastic random searches instead of requiring a derivative information in which HMCR and PAR are responsible to obviate the requirement in adopted derivative information (Yadav et al., 2012). Secondly, HS imposes a small amount of mathematical prerequisite that is effortless to overcome various problems merged in engineering optimisation problems and also entail a few parameters (Fesanghary et al., 2008a)(Khazali and Kalantar, 2011). Thirdly, HS is efficient in conducting continuous and discrete variables (Shabani et al., 2017) as well as unnecessary for decision variables to assign an initial value setting. Fourthly, HS possesses a high potential region of the solution space within practical computational time (Kang and Chae, 2017). Finally, HS algorithm can undergo fast search besides being efficient. These characteristics have made the HS more flexible and yield a good result with chances to attain near global solutions (Kang and Chae, 2017)(Alatas, 2010).

The rule of HS encounter amendment by producing a new solution and another adjustment take part after new solutions are generated. These strengthen the search process and allow the algorithm to generate more refine solutions. This research emphasises the proposed method in aspect of improvisation process refined by modifying the main parameters noted as Harmony Memory Consideration Rate (HMCR) and Bandwith (BW) using certain concepts deviated from the original concept. In this research, a new approach was proposed that employs HS to solve scheduling and rostering problems. This approach aims at constructing a better solution while applying the step function, linear function and guitar fret spacing within a reasonable period. The contributions in this research are summarised as follow:

- The idea of step and linear function was embedded in the HMCR parameter in which HMCR is one of the main parameters in HS. With that, three models and variances were suggested namely constant, dynamic increase and dynamic decrease of step function combining with the theory of linear function to come out with three variances. Each model has its own features in terms of how each interval of group iteration is allocated when looking for global optimum solutions. In constant interval of step function, each interval of group interval has constant number of iteration that seeking global solutions. This means each member of iteration in the same group interval have the same behaviour that mapped to the identical value of HMCR. Each number of iteration is given an opportunity to explore the search space solution. While in dynamic increase and dynamic decrease have irregular total number iteration number that responsible in searching good solutions. But the behaviour in looking for a good solution is still the same as in constant interval of iteration.

- The second contribution is on a new constructed formula for distance bandwidth (also main parameter in HS) whereby the knowledge of fret spacing is imitated. By adopting this principle, this research was able to allow small distance until the greatest distance of bandwidth being covered. In other words, every decision variable can be changed to any value within the permissible range of solutions together with the aid from random numbers defining a sequence number every time it is generated.

The remaining sections of the chapter are organised as follow. Section 1.1 describes the introduction of the research. Section 1.2 discusses the research background, while Section 1.3 presents the problem statement. In Section 1.4, the research objective is presented. Section 1.5 performs research methodology, Section 1.6 discusses the research outline and Section 1.7 concludes the whole chapter.

1.2 Research Background

Optimisation has a vital role in computer science, artificial intelligence, operational research and other related fields (Kunche and Reddy, 2016). Nocedal and Wright (1999) discussed on how people optimise their problems in daily life. Decision making problem in