SOLVING GATE ALLOCATION PROBLEM (AGAP) USING DISTANCE-EVALUATED PARTICLE SWARM OPTIMIZATION (DEPSO)

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering in Mechatronics.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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LIST OF ABBREVIATIONS

AGAP	Airport Gate Allocation Problem
COP	Combinatorial Optimization Problem
PSO	Particle Swarm Optimization
BPSO	Binary Particle Swarm Optimization
DEPSO	Distance-Evaluated Particle Swarm Optimization
GSA	Gravitational Search Algorithm
BGSA	Binary Gravitational Search Algorithm
SKF	Simulated Kalman Filter
BSKF	Binary Simulated Kalman Filter
PEN	Penang
KBK	Kota Kinabalu
KCH	Kuching
KLIA	Kuala Lumpur International Airport
TW	Time Window
TWD	Total Walking Distance

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ABSTRACT

Assignment of flights to gates at an airport become very complex nowadays, especially for unprepared airport. In this investigation, the airport gate allocation problem is solved using a recently introduced Meta-heuristic and also one of the extensions from Particle Swarm Optimization (PSO) which is called Distance-Evaluated Particle Swarm Optimization (DEPSO). The first objective of this investigation is to minimize the passengers; total walking distance from gate to exit/entrance and from gate to gate (transit). Since the airport gate allocation problem is a discrete combinatorial problem, the original continuous PSO is extended to DEPSO such that PSO can be used to solve these discrete combinatorial problem. After that, the second objectives is to evaluate the performance of the DEPSO manually using Excel. Last but not least, a small real life problem or an application for the case study, an airport with 40 flights, 14 numbers of plane and 16 gates has been successfully optimized using DEPSO algorithm.

ABSTRAK

Tugasan penerbangan kepada pintu gerbang lapangan terbang menjadi semakin susah pada masa kini, terutamanya bagi lapangan terbang yang tidak bersedia. Dalam kajian ini, masalah pengaturan pintu gerbang lapangan terbang di selesaikan menggunakan teknik metaheuristik yang baharu di perkenalkan dan salah satu kesinambungan ataupun olahan daripada 'Particle Swarm Optimization' (Pengoktimum Sekumpulan Zarah) yang di namakan Jarak-Dapatan Pengoktimum sekumpulan Zarah atau Distance-Evaluated Particle Swarm Optimization (DEPSO). Objektif pertama kajian ini adalah meminimakan jumlah jarak jalan penumpang dari pintu gerbang ke pintu keluar/pintu masuk dan dari pintu gerbang k pintu gerbang (transit). Oleh kerana masalah pengaturan pintu gerbang di lapangan terbang ialah masalah kombinasi pengoktimum, PSO di olah menjadi DEPSO supaya PSO dapat di gunakan bagi menyelesaikan masalah kombinasi pengoktimum. Selepas itu, objectif kedua ialah menilai prestasi DEPSO secara manual menggunakan Excel. Akhir sekali, masalah sebenar yang kecil ataupun applikasi kehidupan sebenar, lapangan terbang dengan 40 penerbangan, 14 pesawat dan 16 pintu gerbang telah Berjaya di optimakan menggunakan algoritma DEPSO.

CHAPTER 1

INTRODUCTION

1.1 AIRPORT GATE ALLOCATION PROBLEM (AGAP)

Nowadays, with the huge increasing number of civil airport user the difficulty of airport management has increased drastically. Airport management need to efficiently handling the operations at an airport in order to avoid any accidents or flight delays. Accidents might happen if two adjacent planes taxi-in or taxi-out at the same time and this will cause domino effect which affecting the whole airport's operations. Many researcher focusing on solving Airport Gate Allocation Problem (AGAP) and publishing it in spite of it difficulty being solved because AGAP is one of the most significant daily operations to be optimize to increase airport management efficiency. The purpose of the AGAP is allocating each flight to an available without clashing or any accidents while increasing the passengers' satisfaction and managing airport operations efficiently. The bigger the airport, the harder to solving AGAP. The flights have detailed estimated time arrival (ETA), estimated time departure (ETD), number of passengers and etc.

Airport management team or staff must be cooperate and work hard together in order to optimizing the whole operations at an airport. Gate allocation is a crucial activity that must be handle well first before operating the other support operation to make sure airport operation is smoothly operated. International airport usually handle hundreds of domestic and international flights daily, not optimized gate allocation might reducing the airport operations efficiency and causing flight delays, scanty customer satisfaction, ground congestion and etc.

AGAP was categorized as a combinatorial optimization problem which is difficult to solve but it is easy to understand. AGAP is influenced by support operations at an airport such as flights, gates, ETA, ETD, gate facilities and etc. Thus, overall airport operations will be affected if these interdependent resources does not handled well in term of usage. Moreover, although AGAP is a motionless or unchanging and fixed process, it has to deal with some momentary changes such as flight delays and emergency flights due to bad weather and etc. under the dynamic and uncertain environment of the airport in the last-ditch period. For example, a substantial delayed arrival of one specific flight may generate a series of problems and lead to a traffic standstill throughout the corresponding section of airport operation. In this case, from a practical point of view, an optimal or more effective gate assignment should be flexible for compensating the minor delays or temporary changes subject to uncertainties.

1.2 PROJECT BACKGROUND

Since 1974, various optimization method have been proposed in the conjunction to solve AGAP. Slow growth in the research interest in AGAP within 25 years ago show only 15 publications about AGAP were released. However, the researchers interest in this field were showed after 2000 until nowadays with many AGAP published using numerous proposed algorithm such as Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Genetic Algorithm (GA), Gravitational Search Algorithm (GSA) and many else. AGAP objective is problem varied and it is depended on the researcher interest point of view. The previous proposed objectives are to maximizing the available gates usage at an airport, reducing the clashing planes at certain gates with safety measure to avoid any unnecessary planes' accidents, and decrease flights delay. Figure 2.1 below is an example that cause for delay at airport. Another point of view is as an airlines owner. Their goals were to increase the customer satisfaction with minimizing the passenger walking distance between gates and minimizing the travelling distance from runway to the gate.

Figure 1.1: Plane caught fire at airport (causing delay).

Source: "Google image."

AGAP objectives can be categorized in five parts (Dorndorf et al. 2012). The objectives are costly aircraft towing process must be minimized, reducing passengers' shortest total walking distance, reducing the eccentricities in the flights schedule, reducing the number of ungated planes and maximizing the preferences (i.e., certain aircrafts should go for particular gates). They also stated three commonly used restrictions or limitation for AGAP, which are the fact that only one plane can be gated in a defined time window, the fulfillment of the space restriction and service requirements, and the assurance of getting a minimum time between sequent planes and a minimum ground time.

From a mathematical view, AGAP has been created as integer, binary, or mixed integer, general linear or nonlinear models. Detailed formulation as binary or mixed binary quadratic models has also been introduced. Other well-known related problems in combinatorial optimization problems such as quadratic assignment problem (QAP), clique partitioning problem (CPP), and scheduling

REFERENCES

This thesis is prepared based on the following references:

1. R. Eberhart, and J. Kennedy, A New Optimizer Using Particles Swarm Theory, Proc. Sixth International Symposium on Micro Machine and Human Science (Nagoya, Japan), IEEE Service Center, Piscataway, NJ, pp. 39-43, 1995.
2. J. Kennedy, and R. Eberhart, ”Particle Swarm Optimization”, IEEE International Conference on Neural Networks (Perth, Australia), IEEE Service Center, Piscataway, NJ, IV, pp. 1942-1948, 1995.
3. Kennedy, J.; Eberhart, R.C. “A discrete binary version of the particle swarm algorithm”, IEEE International Conference on Systems, Man, and Cybernetics, 1997.
4. Mojtaba Ahmadieh Khanesar, Mohammad Teshnehlab, Mahdi Aliyari Shoorehdeli, A Novel Binary Particle Swarm Optimization, in: Proceedings of the 15th Mediterranean Conference on Control & Automation, July 27–29, 2007.
5. Rashedi, E., Nezamabadi-pour, H., and Saryazdi. S. 2009. BGSA: binary gravitational search algorithm. Natural Computing, Vol. 9, Issue 3, pp. 727-745.
6. Yusof, ZM, Ibrahim, Z, Ibrahim, I, Azmi, KZM, Aziz, NAA, Aziz, NHA, Mohamad, MS. 2015. "Distance evaluated simulated kalman filter for combinatorial optimization problem". International Conference on Electrical Control and Computer Engineering 2015.
7. D. P. Rini, S. M. Shamsuddin, S. S. Yuhaniz. “Particle Swarm Optimization: Technique, System and Challenges”. International Journal of Computer Applications (0975 – 8887), Volume 14– No.1, January 2011.
8. Xiao-Bing Hu and Ezequiel Di Paolo. “An Efficient Genetic Algorithm with Uniform Crossover for the Multi-Objective Airport Gate Assignment Problem”. Computers & Operations Research 32, 1867–1880 (2003)

9. Ding, H., Lim, A., Rodrigues, B., Zhu, Y.: The over-constrained airport gate assignment problem. Computers & Operations Research 32, 1867–1880 (2005).
10. Ding, H., Lim, A., Rodrigues, B. and Zhu, Y. (2004b) Aircraft and gate scheduling optimization at airports, in Proceedings of the 37th Annual Hawaii International Conference on System Sciences, IEEE, Piscataway, NJ, pp. 74–81.
11. Dorndorf, U. (2002) Project Scheduling with Time Windows: From Theory to Applications, Physica, Heidelberg, Germany.
12. Xu, J. and Bailey, G. 2001. The airport gate assignment problem: mathematical model and a tabu search algorithm. In Proceedings of the 34th Hawaii International Conference on System Sciences (3): 10-19.
13. A. Mustapa, Z. Ibrahim, Z. Md. Yusof, I. Ibrahim. Global Optimum Distance Evaluated Particle Swarm Optimization for Combinatorial Optimization Problem. The National Conference for Postgraduate Research 2016, Universiti Malaysia Pahang.