FLOWSHOP SCHEDULING USING ARTIFICIAL BEE COLONY (ABC) ALGORITHM WITH VARYING ONLOOKER BEES APPROACHES

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Dedicated to my beloved parents

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ABSTRACT

The common objectives in permutation flowshop scheduling problem are to minimize the total completion time or formally called as makespan and tardiness. Artificial Bee Colony (ABC) algorithm is one of the methods used to solve the flowshop scheduling problem but only a few researches have been found using this method in this area. Therefore, ABC algorithm is proposed to solve the flowshop scheduling problem in this research. The main objective of this research is to develop a computer program with capability of manipulating the onlooker bee approaches in ABC Algorithm for solving flowshop scheduling problem. The research also analyzes the performance of the ABC algorithm using three different onlooker bee approaches. A simulation computer program was developed using Visual Basic Editor in Microsoft excel 2007. In this simulation, onlooker bees as the important bee make decision to choose the specific method. The performance of the ABC algorithm was evaluated through three different onlooker approaches i.e. method 3+0+0 (three onlooker bees are dedicated to the best employee bee), method 2+1+0 (two onlooker bees are dedicated to the best employee bee and one onlooker bee is dedicated to second best employee bee) and method 1+1+1 (one onlooker bee is dedicated to each employee bee). All the average percentage makespan difference from three onlooker approaches was compared and the lowest average percentage makespan difference was selected as the best method. The simulation results indicated that method 2+1+0 produces best result at low iterations of 102 and below. At high iterations of 204 and above, method 3+0+0 dominates the best performance. Based on this finding, the selection of the best method can be decided based on the iteration time available. If iteration available is long, method 3+0+0 is more appropriate, otherwise method 2+1+0 is the best choice. The findings from this research can be used by system developer or computer programmer to search the optimum sequence during the manufacturing process and improve the flowshop scheduling.

ABSTRAK

Objektif yang biasa ditetapkan dalam menyelesaikan masalah penjadualan susun atur ialah mengurangkan jumlah masa untuk menyiapkan sesuatu produk atau juga dikenali sebagai 'makespan'dan masalah kelewatan penghasilan produk. '*Artificial Bee Colony (ABC) Algorithm*' adalah satu algoritma baru yang boleh digunakan untuk menyelesaikan masalan dalam penjadualan susun atur, di mana hanya beberapa kajian telah dijumpai. Oleh sebab itu, algoritma ABC dicadangkan untuk menyelesaikan masalah susun atur dalam kajian ini. Objektif utama kajian ini adalah untuk membentuk satu program komputer dengan pendekatan memanipulasi keupayaan lebah '*onlooker*' menggunakan algoritma ABC untuk menyelesaikan masalah penjadualan susun atur. Kajian ini juga menganalisis prestasi algorithma ABC dengan menggunakan tiga pendekatan lebah '*onlooker*' yang berbeza. Simulasi program computer ini dibuat menggunakan '*visual basic editor'* dalam *'microsoft excel 2007'*. Prestasi algorithma ABC ini dinilai menggunakan pendekatan lebah '*onlooker*' yang berbeza iaitu kaedah 3+0+0 (3 ekor lebah '*onlooker*' didedikasikan untuk lebah '*employee*' yang terbaik), kaedah 2+1+0 (2 ekor lebah '*onlooker*' didedikasikan untuk lebah '*employee*' yang terbaik dan seekor lebah '*onlooker*' didedikasikan untuk lebah '*employee*' kedua terbaik) dan kaedah 1+1+1 (setiap lebah '*onlooker*' didedikasikan untuk setiap lebah '*employee*'). Semua purata peratus perbezaan makespan dibandingkan dan dinilai. Perbezaan makespan yang terendah talah dipilih sebagai kaedah yang terbaik. Hasil kajian ini menunjukkan kaedah 2+1+0 telah menghasilkan keputusan yang baik pada iterasi 102 dan kurang. Pada iterasi 204 dan lebih, kaedah 3+0+0 menunjukkan prestasi yang lebih baik. Daripada keputusan ini, pemilihanan kaedah yang terbaik boleh dipilih berdasarkan masa iterasi yang ada. Sekiranya masa iterasi adalah lama, kaedah yang terbaik ialah 3+0+0, jika tidak kaedah 2+1+0 adalah yang terbaik. Hasil daripada kajian ini boleh digunakan oleh pemaju sistem dan seseorang pengaturcara untuk mencari urutan optima semasa proses pembuatan dan menambahbaik penjadualan susun atur.

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LIST OF SYMBOLS AND ABREVIATIONS

D	-	Dimension
EB	-	Employee Bees
fit	-	Fitness Value
i	-	Machine
j	-	Job
LB	-	Lower Bound
m	-	Number of Machine
max	-	Maximum
MCN	-	Maximum Cycle Number
min	-	Minimum
n	-	Number of Job
OL	-	Onlooker Bees
p	-	Processing Time
r	-	Random Number Between [0,1]
SN	-	Solution Number
UB	-	Upper Bound
$\emptyset$	-	Random Number Between [-1,1]
(c_{max})	-	Total Completion Time
$f(x_1)$	-	Fitness of each Food Source
p_i	-	Probability Value
$x_{\min}^{j}$	-	Lower Bound of the Searching Area
$x_{\max}^{j}$	-	Upper Bound of the Searching Area

CHAPTER 1

INTRODUCTION

1.1 Research Background

Scheduling is a decision making process used in manufacturing and services industries. One of the main objectives of scheduling applications in both industries is to minimize the maximum completion time or makespan. It is important to minimize the makespan because it ensures high productivity to production line in manufacturing industries. This objective can also be reached in permutation flowshop scheduling problem.

One of the methods to solve the permutation flowshop scheduling problem is using Artificial Bee Colony Algorithm. Artificial Bee Colony (ABC) Algorithm is the concept proposed by Karaboga in 2005. Artificial bee colony algorithm concept is simple, easy to implement, fewer control parameters setting (Bonabeau *et al.*, 1999), (Bao & Zeng, 2009) and is known to be better than other algorithm for global optimization (Karaboga & Basturk, 2008), (Mala *et al.*, 2010), (Karaboga & Akay, 2009), (Marinakis, *et al.*, 2009). This algorithm use the concept based on the foraging behavior of honey bee swarms.

Bee swarm consists of three group i.e. employee bees, onlooker bees and scout bees. Employee bee is responsible to search the new food source. Employee bee used waggle dance to communicate with other bees. Onlooker bees will wait in the hive and receive the information from employee bee. Onlooker bee is responsible for making decision to choose the best food source. Scout bee is responsible to find the new food source randomly.

The best food source is selected by using greedy selection process. Greedy selection process means the best food source found will replace the old food source if a new food source is better than old food source. In ABC algorithm, the new food source that bee found will replace the old food source if the new food source is better than before. The old food source will be maintained if the old food source is better than the new food source.

1.2 Problem Statement

The most common objectives function in flowshop scheduling problem are to minimize makespan, bottleneck and tardiness. This research is focused to minimize the makespan for the flowshop scheduling problem. Flowshop scheduling involves a few jobs to be processed in a set of machines. In order to solve the flowshop problem with the makespan criterion, the best permutations have to be obtained. However, it is complicated to find the best permutation for a problem with many jobs and machines.

Several heuristics have been developed to solve the permutation flowshop problem such as NEH Heuristics (Nawaz *et al.*, 1983), Gupta Heuristics (Gupta, 1971), Palmer Heuristics (Palmer, 1965) and others. Nowadays, the trend is changing to used swarm intelligent concept to solve the flowshop scheduling problem. One of the method that used swarm intelligence concept is Artificial Bee Colony (ABC). The ABC have been used to solve the flowshop scheduling problem, which can be found in Yan & San, (2011) that developed Hybrid Discrete Artificial Bee Colony (HDABC) Algorithm for the permutation flowshop scheduling. Before that, a Discrete Artificial Bee Colony (DABC) algorithm (Fatih *et al.*, 2010a) was developed to solve the permutation flowshop scheduling problem. However, it is difficult and takes a long time to find the minimum makespan. Besides that, the makesan value obtained is not the best makespan to solve the permutation flowshop scheduling problem.

ABC algorithm is relatively very new area being studied for the flowshop scheduling. There were not many literatures found explaining the thorough concept and detail analysis of the ABC performance. Therefore, this research will be focused to use the ABC algorithm and study its characteristics and performance for solving the flowshop scheduling. Based on the basic ABC algorithm, this research will propose new procedure in ABC algorithm by using three different onlooker bee approaches to find the minimum makespan. This is because, onlooker bee have important parts in ABC algorithm, which is to produce new solutions based on the probability of the solution found by the employee bee (Karaboga and Basturk, 2007). Therefore, the various approaches of the onlooker bees and its related performance have been investigated to choose the best approaches of the onlooker bees.

1.3 Objectives

The main objectives of this research are:

1. To develop a computer program with capability of manipulating the onlooker bees approaches in ABC Algorithm for solving flowshop scheduling problem.
2. To analyze the performance of the ABC algorithm using three different onlooker bees approaches.

1.4 Project Scope

To achieve the objective stated above, the boundary is setup for the element involved in the project as the following:

1.4.1 Scheduling

a) This project has been used for six jobs and three machines.
b) The sample data for this project is generated randomly.
c) The type of manufacturing flow is flowshop.

1.4.2 Artificial Bee Colony system development

a) The system is developed and analyze using Microsoft excel
b) The performance of ABC is evaluated using 100 sets of randomly generated data.

1.5 Project Justification

This research investigates three different approaches of onlooker bees that affect the performance of the ABC algorithm in flowshop scheduling. The findings of this investigation have contributed to the area of flowshop scheduling using ABC algorithm.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review of the project. The literature reviews for this study were extracted from the books and research journals. The areas described in this chapter are the flowshop scheduling problem, Artificial Bee Colony heuristics and application of Artificial Bee Colony algorithm.

2.2 Flowshop scheduling

Scheduling is considered to be a major task for shop floor productivity improvement. Scheduling is the allocation of resources applying the limited factor of time and cost to perform a collection of tasks. Flowshop in scheduling can be briefly described as a series of *m* machine in manufacturing. Each job has to be processed on each one of the *m* machine. All the jobs need to follow the same route. Flowshop scheduling used first in first out disciplines in which the job cannot go to another machine while waiting in queue.

Haller (1959) classifies the flowshop as a conservative assembly line with several different characteristics. The first characteristic of flowshop scheduling is that it has to be prepared to handle a variety of jobs compared with standard products produce by an assembly line. The second characteristics of the flowshop are a job in flowshop does not need to be processed on all machines. This means a job can skip some operations according to its technology requirements. However, all jobs are necessary to be moved from one station to another without skipping any work station.

The third characteristics of the flowshop is that each machine is independent of other machine and can be loaded independently, where in assembly line operations, each work station depends on the preceding one. The last characteristic of the flowshop is each job has its own processing time on the machine in a flowshop. However, all units of a product have a standard time at each work station in assembly line (Ashour, 1972).

2.2.1 Flowshop scheduling problem

In manufacturing industries, flowshop scheduling is one of the most prevalent problems in deterministic scheduling (Cheng *et al*., 2009). The main problem in flowshop scheduling is to minimize the total completion time or makespan. The flowshop scheduling problem consists of 'M' machines and 'N' jobs. The order in which the machines are required to process a job is called process sequences of that job. The process sequence of all job are the same but the processing time for various job maybe different.

A few of the problems that frequently encountered in the production systems are when the machine needs to move from one part to another part of the processing system, setup time and cost incurred to change accessories and machine setting. Several heuristics have been developed to solve this problem. In 1983, Nawaz *et al.* (1983) proposed a constructive heuristics known as NEH heuristics. In 1971, Gupta (1971) proposed new heuristics known as Gupta heuristics. Another heuristics had been developed to solve flowshop scheduling problem is Palmer heuristics (Palmer, 1965) created by Palmer in 1965.

	M_1	M_2	M_3	M_4
J_1	1	2	2	1
J_2	1	1	2	2
J_3	2	1	1	2
J_4	1	3	2	1

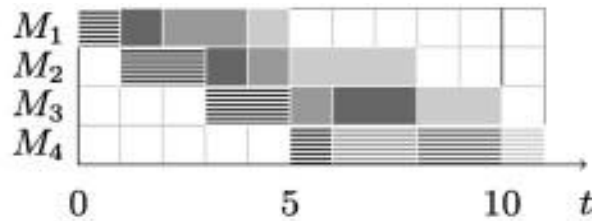

Figure 2.1: An instance of a flowshop, left: Processing times, right: Optimal schedule. (Alexander *et al.*, 2014)

Figure 2.1 shows the example of flowshop scheduling problem. The left side shows the processing times for four machines and four jobs, and in the right side is the optimal schedule for this flowshop. Alexander *et al.*(2014) defined the makespan value for schedule as critical path, which a sequence of conservative operations on the same machine. A critical path can be decomposed in maximal blocks of operations that are executed in the same machine.

2.2.2 Permutation flowshop scheduling problem

The permutation flowshop scheduling find the best permutation to minimize the maximum completion time or formally called as makespan. Solution to permutation flowshop scheduling problem is represented by the permutation of n jobs. There is a set of n jobs, $\pi = \pi_1, \pi_2, \ldots, \pi_n$. Each job processed on m operations. Every operation performed by different machine. The processing time p_{ij} for job j and using machine i is given. The best permutation for jobs $\pi^* = \{\pi_1^*, \pi_2^*, \ldots, \pi_n^*\}$ to be processed on each machine and can be found using the permutation flowshop scheduling. Let, $C(\pi_j,m)$ denotes the completion time for the job π_j using machine m. Given the job permutation π, the completion time for the n job, m machine problem is calculated as follows.

$$c(\pi_1, 1) = \rho_{\pi 1}, 1 \qquad (2.1)$$

$$c(\pi_j, 1) = c(\pi_j - 1, 1) + \rho_{\pi j,1} \quad j = 2, \ldots, n \qquad (2.2)$$

$$c(\pi_1, i) = c(\pi_1, i - 1) + \rho_{\pi 1,i} \quad i = 2, \ldots, m \qquad (2.3)$$

$$c(\pi_j, i) = max[\, c(\pi_j - 1, i), c(\pi_j, i - 1)] + \rho_{\pi j,i} \qquad (2.4)$$

$$j = 2, \ldots, n \qquad I = 2, \ldots, m$$

The makespan for a permutation π is equal to the completion time for the last job π_n using the last machine m. The completion time for the permutation π is $c_{max}(\pi)=c(\pi_n, m)$ (Yan & San, 2011).

2.3 Artificial Bee Colony heuristics

Artificial bee colony is an algorithm that use swarm intelligence as a base to solve a problem. Application based on swarm intelligence means trial to create any algorithm to solve problem based on behavior of social insect colony or other animal societies. For artificial bee colony, it uses behavior of honeybees as a model to find the solution for any problem, especially to solve the numerical optimization problem (Adil *et al.*, 2007).

Heuristics refers to experience based on the techniques for problem solving, learning and discovery. Heuristic methods are used to speed up the process of finding a good enough solution, where an exhaustive search is impractical.

Lately, several heuristics were developed to solve the permutation flowshop problem. This heuristics applied the same concept as artificial bee colony. Palmer (1965) develops Palmer Heuristics based on swarm intelligence concept. Gupta developed the Gupta Heuristics (Cheng *et al.*, 2009) and Nawaz developed the NEH heuristic (Bonabeau *et al.*, 1999). Until today, NEH heuristic is one of the best constructive heuristics. After that, Bao & Zeng (2009) proposed the improvement for NEH heuristics for the permutation flowshop problem in 2008.

2.3.1 Behavior of honeybees.

Bee algorithms were created based on behavior of honeybees. Overall, the behaviors of honeybees can be divided into three different groups. The names of the groups are foraging behavior, marriage behavior and queen bee concept (Adil *et al*., 2007). Foraging behavior is related to the feeding process of honeybees. It includes different aspects such as division of labor and specialization. This behavior uses the waggle dance as means of communication with other bees to send the information. This type of communication is applied to find the new food source.

The second behavior of honeybees is marriage behavior. This behavior starts with a waggle dance of the queen. After that, the queen and the drones mate during her mating flight. The sperm from the different drones deposited in the queen spermatheca to form the genetic pool for the hive. Finally, the sperm retrieve from the spermatheca randomly for every fertilized egg from the queen. For this behavior, the queen is able to mate more than once but the drone only mates once and die after the mating dance.

The last behavior of the honeybees is the queen bee. The queen bee is the only bee that mates with other bees. The best solution in the group is selected to crossbreed with other bees. This behavior is also applied to genetic algorithms.

2.3.2 Foraging behavior

A branch of nature inspired algorithms which are called as swarm intelligence is focused on insect behavior in order to develop some meta-heuristics which can replicate insect problem solution abilities. Interaction between insects contributes to the collective intelligence of the social insect colony. These communication systems between insects have been adapted to the scientific problem (Karaboga & Basturk, 2007).

One of the examples of interactive behavior is the waggle dance of bees during the food procuring. By performing this dance, successful foragers share the information about the direction and distance to patches of flower and the amount of nectar within this

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