TABU SEARCH METHOD FOR SOLVING MULTIOBJECTIVE JOB SHOP SCHEDULING PROBLEM

NOR FAUZANA BINTI AWANG

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To my beloved parents

Hj. Awang Bebakar and Hjh. Rohani Mahmud

siblings

Mohd Ruzman Awang & Afeefa Nawfa Amran

Nor Farahiyah Awang & Nasrullah Yahaya

Muhd Hazimin Awang & Norasiah Dahalil

Nor Hidayah Awang

Nor Hafilah Awang

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ABSTRACT

Scheduling is widely studied and it involves of complex combinatorial optimization problems. A job shop scheduling problem (JSSP) is one of the common scheduling problems. The application of it ranges from manufacturing to services industries. It can be considered as a NP-hard problem. A lot of research has been performed in this particular area to obtain an effective schedule jobs for various objectives. More than one objective in a single problem is considered multiobjective problem. Two objectives, which are the maximum completion time (makespan) and total weighted tardiness, are measured simultaneously to improve the performance of the schedule. In this study, metaheuristic method known as tabu search algorithm is proposed to tackle the problem. But, first of all Giffler and Thompson (GT) algorithm will be applied to obtain the potential initial solution for the respective problem. Benchmark problem is used to evaluate and study the performance of the proposed algorithm. Results shows that tabu search provide a better solution compared to simulated annealing method.

ABSTRAK

Kajian tentang masalah penjadualan tugas telah banyak dijalankan dan ianya melibatkan gabungan masalah pengoptimuman yang kompleks. Salah satu masalah penjadualan yang biasa digunakan ialah masalah penjadualan *job shop*. Aplikasi bagi masalah ini termasuklah dalam sektor pembuatan dan perkhidmatan. Ianya boleh dikategorikan sebagai masalah penjadualan *NP-hard*. Banyak kajian telah dilaksanakan bagi mendapatkan jadual kerja yang berkesan berdasarkan objektif kajian yang pelbagai. Bagi satu permasalahan yang mempunyai lebih daripada satu objektif kajian boleh diketegorikan sebagai permasalahan multi-objektif. Dua objektif iaitu *makespan* dan *total weighted tardiness* telah diambil kira bagi memperbaiki masalah penjadualan berkenaan. Dalam kajian ini, satu kaedah *metaheuristic* yang dikenali sebagai *tabu search* telah dicadangkan. Namun, algoritma Giffler dan Thompson (GT) akan digunakan terlebih dahulu bagi mendapatkan penyelesaian awal bagi setiap masalah. Satu permasalahan telah digunakan bagi membandingkan kaedah yang dicadangkan. Hasil kajian menunjukkan *tabu search* menghasilkan penyelesaian yang lebih baik berbanding *simulated annealing*.

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LIST OF SYMBOLS AND ABBREVIATIONS

JSSP	Job shop scheduling problem
TS	Tabu search
SA	Simulated annealing
GA	Genetic algorithm
NP-hard	Nondeterministic polynomial-time hard
J_n	The *n*th job
M_m	The *m*th machine
TWT	Total weighted tardiness
C_{max}	The makespan
O_{jk}	The operation of job *j* on machine *k*
C_j	The completion time of job *j*
p_{jk}	The processing time of job *j* on machine *k*
p'_{jk}	The minimum processing time of job *j* on machine *k*
t_{jk}	The starting time of operation O_{jk}
t'_{jk}	The earliest starting time of operation O_{jk}
w_j	The preset weight that are given for each job *j*

CHAPTER 1

INTRODUCTION

1.1 Introduction

Scheduling can be defined as a decision making process over a period of time (Pinedo, 2008). It deals with the allocation of tasks in a given time. It also contains one or more goals or we can call it objectives that need to be fulfilled at the end of it. Scheduling problem can be modelled as an assignment problem which indicates a large class of combinatorial optimization problems (Pierre, 2010). For some cases, it is very hard to find the optimal solution. If we cannot solve it in polynomial time, we called it NP-hard problem.

In general, scheduling problem can be categorized in three sets which are set $\mathcal{T}$, set $\mathcal{P}$ and set $\mathcal{R}$. Set $\mathcal{T} = \{T_1, T_2, \dots, T_n\}$ of n tasks, set $\mathcal{P} = \{P_1, P_2, \dots, P_m\}$ of m processors (machines) and set $\mathcal{R} = \{R_1, R_2, \dots, R_s\}$ of s types of additional resources $\mathcal{R}$. So, we can say that scheduling is a process of assigning processors from $\mathcal{P}$ and resources from $\mathcal{R}$ to task from $\mathcal{T}$ in order to complete all tasks under a certain constraints (Blazewicz *et al.*, 2007). Basically, there are two general constraints in

classical scheduling theory which are each task need to be processed by at most one processor at a time and each processor is capable of processing at least one task at a time. Scheduling problems occur in many areas in our daily life. The most noticeable field that use scheduling in their operation is in manufacturing industries. Some said it also can be applied in service industries.

1.2 Background of the Problem

Scheduling and sequencing play an important role in a decision making process. Scheduling is done according to time and resource capacity while sequencing is the order of the task in a chain. In other word, sequencing is done based on the information from scheduling parameter. Another definition of scheduling is given by Tamilarasi (2010). He says that scheduling is a problem of finding an optimal sequence to execute a finite set of operations satisfying most of the constraints.

According to Pawel (2005), scheduling is a process of assigning one or more resources to activities over a specific amount of time. Resource that mentioned above is referred to a machine and any activity run on the machine is called operation. The main concept of scheduling problem is to find the most optimal schedule of that problem. The optimal schedule will give the best option of possible sequence in a process. In the problem that involves scheduling, three general conditions have been highlighted. First, a job cannot be processed by two machines at one. Next, a machine cannot process two jobs at once and the last one is technological constraints related to the specific problem must be satisfied.

Scheduling problem can be classified into three groups of parameters which are machine environment, job characteristic and optimality criteria (Pawel, 2005). Machine environment represents different formation of machines in the system. There are two types of cases that can be considered in machine environment which are single-stage production system and multi-stage production system. During this study, we will only focus on multi-stage production system. In multi-stage production system, jobs required operations on various machines and each machine must have different function. To be more specific, it has three sub-problems that can be considered which are flow shop, job shop and open shop (Pinedo, 2008).

For this study, we will discuss only on job shop scheduling problem. Job shop is a model of solution for a scheduling and sequencing problem. We use the job shop model when there are m machines and each n job has its own route or order to follow (Pinedo, 2008). In certain cases, Pinedo (2008) says that flow shop model will be applied if each job has to follow the same order of processing. In his book, he also mentioned that if n jobs are freely to use the m machines in any order, the model is considered to be open shop model. Those three models are commonly known by other researchers. Job shop scheduling problem (JSSP) is one of the problem in optimization and research operation field. This problem can be solved using a few methods such as simulated annealing (SA), genetic algorithm (GA) and tabu search (TS).

In the last decades, the job shop scheduling problem has captured the attention of many researchers. Because of their interest in this problem, many research methodologies have been proposed. It seems that there are many research conducted using a single objective. This is because multiobjective problem is difficult to handle. There is no method that able to solve multiobjective problem in polynomial time. So that multiobjective cases can be considered as NP-hard problem. Because of that reasons, we will try to solve multiobjective job shop scheduling problem that consist of two objectives which are minimizing the

makespan and total weighted tardiness by using tabu search method. Figure 1.1 provides the framework of this study.

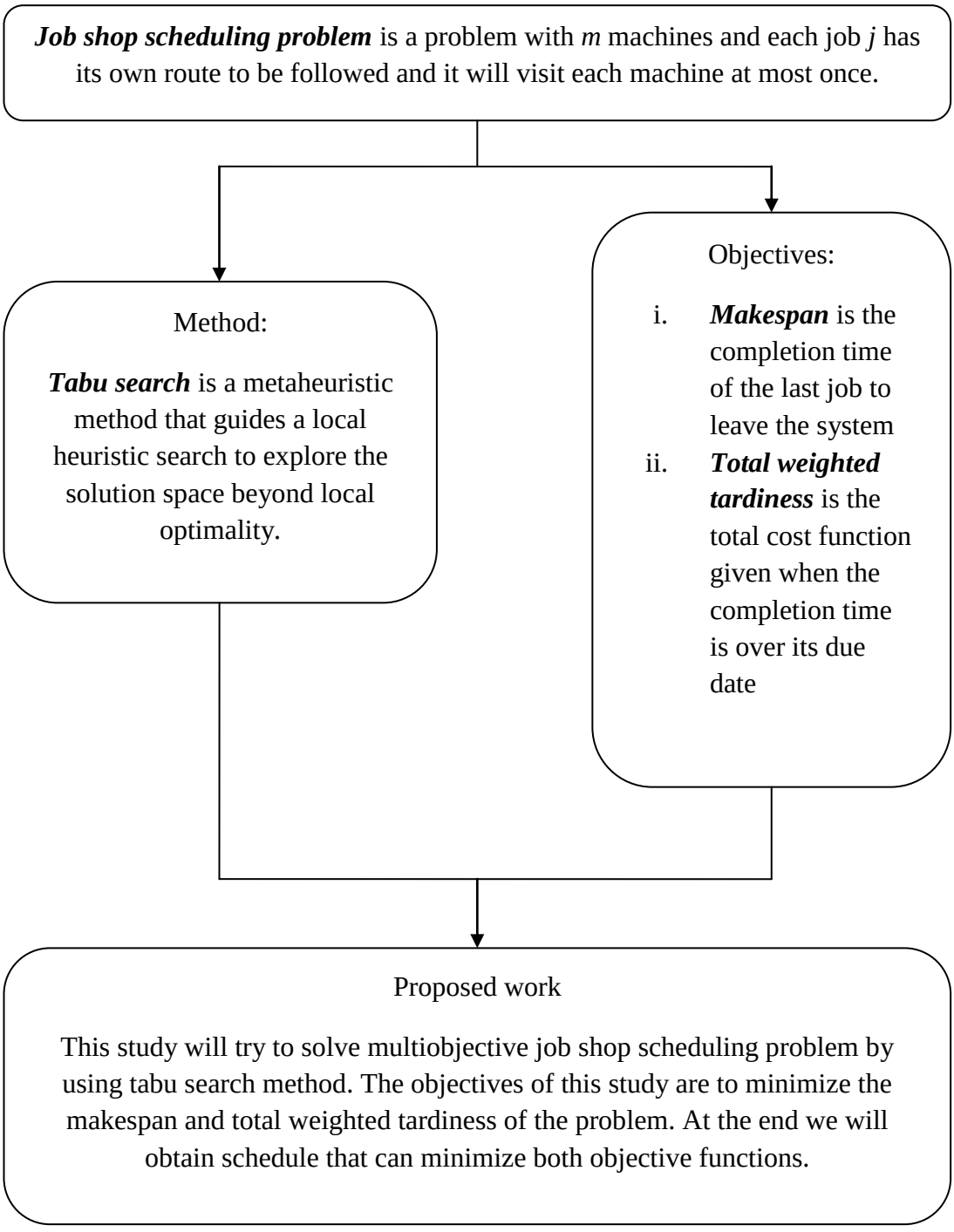

Figure 1.1 Scenario leading to the problem

1.3 Statement of the Problem

Job shop scheduling problem (JSSP) consists of a set of j jobs that need to undergo a process on a set m machines. The set of jobs can be denoted by $J = \{J_1, J_2, ..., J_n\}$ and the set of machines can be written as $M = \{M_1, M_2, ..., M_m\}$. This problem assumes that only one job can be processed on a machine at a time. The process of a job on a machine is called an operation (O_{ij}) and each operation has its own processing time, p_{ij}. In job shop problem each job has its own predetermined route to follow. Meaning that, the sequence of machines for each job is different. Hence the sequence of the machines is known as technological constraint.

There are two main objective functions highlighted in this study. The first objective is to minimize the makespan, C_{max}. Makespan can be defined as completion time of the last job to leave the system and can be denoted as $C_{max} = max\ (C_1, C_2, C_3, \ldots, C_n)$. The second is to minimize the total weighted tardiness, $\sum w_j T_j$. The weight w_j is basically a priority factor that signifying the important of job j during the process. Meanwhile, T_j is the tardiness of job j and it can be defined as $T_j = max(C_j - d_j, 0)$. At the end of this study, we will use equation given by $\min Z = a_1 C_{max} + a_2 \sum w_j T_j$ to minimize both objectives where a_1 and a_2 are the determinant coefficient that indicate which one is the most important for the problem.

1.4 Objectives of the Study

In this study, we consider three main objectives that need to be focused. Those three objectives of this study are as follows:

a) To propose an algorithm of tabu search (TS) in solving multiobjective job shop scheduling problem (JSSP).

b) To get the optimal schedule for makespan and total weighted tardiness respectively.

c) To obtain the best schedule that minimizes the value of weighted sum for both makespan and total weighted tardiness.

1.5 Scope of the Study

This study will be focused on classical job shop problem based on tabu search (TS) method. It deals with static and deterministic problem where all the information is available at time zero and known in advance. Since all the calculations are done by using Microsoft excel, only small problems will be considered. Thus this study will only covers 3x3 JSSP, 4x4 JSSP and 6x6 JSSP. There are two objective functions that will be focused in this study which are minimizing the makespan and total weighted tardiness. Values for both objectives will be shown in table at every iteration. GT algorithm will be used to obtain initial solution for each problem and neighbourhood type 1 (N1) will be applied at each iteration to obtain new neighbours.

1.6 Significance of the Study

Scheduling involves taking decision regarding the allocation of available capacity or resources to solve problems regarding on jobs, activities, tasks and production over time. The application of scheduling can be seen on scheduling of jobs in factories and companies and also scheduling employee work hours (Pedersen, 2009). Pinedo (2008) states a few more application of job shop scheduling in real life. The present research is conducted in developing the tabu search algorithm to solve JSSP. It helps in minimizing the total completion time of the whole process (makespan) and gives the best schedule that can minimize total weighted tardiness.

1.7 Layout of the Dissertation

This thesis contains five chapter overall. Chapter 1 is the overview of this study. It helps to understand the purpose and the objective that we seek during this time. Chapter 2 presents the literature review on job shop scheduling problem, multiobjective criteria and also methods to solve this problem. Next, we have chapter 3 that will discuss the procedure that will be followed to achieve the stated objectives. Meanwhile, in chapter 4 there are a few examples of job shop scheduling problem. There are 3x3 JSSP, 4x4 JSSP and 6x6 JSSP that are calculated by using tabu search method. Finally, chapter 5 provide summary of this study with some recommendations that might help in future work.

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