NATIONAL TECHNICAL UNIVERSITY COLLEGE OF MALAYSIA

A Search Method for Flowshop Scheduling Problem

Thesis submitted in accordance with the requirements of the National Technical University College of Malaysia for the Degree of Bachelor of Engineering (Honours) Manufacturing (Process)

By

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APPROVAL

This thesis submitted to the senate of KUTKM and has been accepted as fulfillment of the requirement for the Degree of Bachelor of Manufacturing Engineering (Honours) (Manufacturing Process). The members of the supervisory committee are as follows:

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DECLARATION

I hereby, declare this thesis entitled "A Search Method for Flowshop Scheduling Problem" is the results of my own research except as cited in the reference.

Signature	:………………………………………….
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DEDICATION

I want to dedicate this work to my family, my supervisor Dr Bagas Wardono, all Faculty of Manufacturing Engineering's lecturers, my housemate and also to all my friends for their endless support for this thesis.

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ABSTRACT

Search method is one of the approaches that had been considered important in improving the job completion time in the flowshop scheduling. There are many methods available to obtain such solutions, including constructive heuristics, search methods and enumeration. Search method is much better compare to the enumeration technique and constructive heuristics because this technique is suitable for large size problems and gives good results without depending on the structure of the algorithms and the structure of the problems. In this study, analysis will be develop base on the search method to solve the scheduling problem (minimize the *makespan*).

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

TS	-	Tabu Search
LI	-	Local Improvement Procedure
LS	-	Local Search
GA	-	Genetic Algorithm
SA	-	Simulated Annealing
s	-	Current solution
n	-	Numbers of Job
m	-	Numbers of machine
p_{ij}	-	Processing times of the jobs at each machine
f(s)	-	Objective function
N(s)	-	Neighborhood
s'	-	Neighbor solution
C_{max}	-	The job completion time
$C_{max}(s')$	-	The job completion time (neighbor solution)
LI	-	Local Improvement Procedure
TS	-	Tabu Search
T(s,k)	-	Tabu list
FSP	-	Flowshop Scheduling Problem

CHAPTER I
INTRODUCTION

1.1 Background

Today the economic for the nation for many countries including Malaysia is generated from the manufacturing industries sector. The main focus in the manufacturing industrial today is the number of production made in the specific duration. The incomes for the industries come from the sales of the production and these numbers of production are currently depending on the time taken to finish it. So, to maximize the production, one of the solutions is to minimize the time taken to complete the overall jobs or activities.

Arrangement for the job solution have to be determined that give the minimum time that have to be done. Many methods are available to obtain such solutions, including: constructive heuristics, search methods (i.e. Tabu Search and Local Improvement Procedure/Local Search), and enumeration. Enumeration technique will give the optimal solution to the problems, but for large problems, this technique is not suitable due to the large number of the solutions. Constructive heuristics might give good results depending on the structure of the algorithms and the structure of the problems. In this study, we will concentrate our focus on search method.

1.2 Problem Statement

One of the problems in industrial manufacturing sector is the flowshop scheduling. In the flowshop scheduling, a set of jobs must to go through several set of machines. It is not a difficult problem if the number of jobs or activities (n) and the number of machines (m) are small. The optimal solution can be determined using enumeration method. But the flowshop problems will be difficult to solve if the number of jobs or activities (n) and the number of machines (m) are considerably high. One of the solutions is using a search method to find the best jobs arrangement. The schematic of the basic flowshop is shown in figure 1.1 below.

There are many methods that can be applied to solve this problem but it is very difficult to determine which method is the best. So in this study, we will make research on these four (4) different search methods, those are Tabu Search (TS), Local Improvement Procedure (LI)/Local Search (LS), Simulated Annealing (SA) and Genetic Algorithm (GA). Previous study on the search method will be analyzed and a discussion and analysis will be performed based on those study.

1.3 Objectives

The main target of this study is to understand the basic principle of the Search Method. Specifically the objectives of this study are:

1. To generate a deep understanding on all these four search method (TS, LS, SA GA) principles.
2. To study differences among search methods.
3. To evaluate the effectiveness of the previous algorithm by comparing the results among each others.
4. To come out with a conclusion regarding to the Search Method.

1.3 Project Scope

In this study, one of our purposes is to design an algorithm as one of solutions to the scheduling problem base on a search method but due to the time constrain, the algorithm is not able to complete. So we continued with making research on previous algorithm done by several people. The scopes for this project study are:

1. The requirements of the study.
2. The factors contribute to the problem
3. The solutions that will be consider for the problem

CHAPTER II
LITERATURE REVIEW

2.1 Scheduling Problems

Scheduling has been defined as the allocation of resources over time to perform a collection of tasks. Scheduling is important in the design and management of a variety of systems with differing tasks and resources. The basic shop scheduling model consists of machines and jobs, each of which consists of a set of operations. Each operation has an associated machine on which it has to be processed for a given length of time. The processing times of operations of a job cannot overlap. Each machine can process at most one operation at a given time.

While each of these systems utilizes different resource classes, assigning times to activities requiring those resources remains the fundamental scheduling problem. It is the time element that distinguishes scheduling from other resource allocation problems. In general, there are two related decisions required as part of the scheduling process:

1. Sequencing the jobs to be processed through the machines.
2. Assignment of time for accomplishing each task.

Time assignment requires dividing tasks among resources and choosing starting times. It must consider relations among tasks such as precedence requirements as well as the availability of limited resources necessary for performing the tasks. Resource assignment in general must consider the availability of specific resource units as well as the suitability of a particular unit for a particular task. The interplay between the task time and resource assignment decisions is therefore at the heart of scheduling.

At this time, multitudes of scheduling problems are under research, rendering possible an abstract general presentation by grouping the main classical problems in five distinct classes:

- *Workshops with only one machine*: There is only one machine which must be used for scheduling the given jobs, under the specified constraints;
- *Flowshop*: There is more than one machine and each job must be processed on each of the machines – the number of operations for each job is equal with the number of machines, the j^{th} operation of each job being processed on machine j;

- *Jobshop*: The problem is formulated under the same terms as for the flowshop problem, having as specific difference the fact that each job has associated a processing order assigned for its operations.
- *Openshop*: The same similarity with the flowshop problem, the processing order for the operations being completely arbitrary the order for processing a job's operations is not relevant; any ordering will do.
- *Mixed workshop*: There is a subset of jobs for which a fixed processing path is specified, the other jobs being scheduled in order to minimize the objective function.

In this study, we focus our investigation on the flowshop scheduling problems with the objective to minimize the *makespan*, which is defined as the completion time of the last job on the last machine.

2.2. Flowshop scheduling problem

The flowshop scheduling problem can be defined as of *n* jobs, and a set of *m* machines. Each job *j* must be scheduled on a predetermined machine for a fixed amount of time, p_{ij}, without interruption, where P_{ij} is the processing time of job *j* on machine *i*, for $j=1\ldots,n$ and $i=1\ldots,m$. No machine may process more than one operation at a time, and each job can only be processes by one machine.

Sequence dependent setup times are a tool for modeling a problem where there are different “classes" of operations which require machines to be reconfigured. For example two tasks in a machine shop may both be performed on the same drill press, but require different drill bits. In an instance of the flowshop scheduling problem with sequence dependent setup times, assign a class identifier C_{max} to each task and impose a fixed setup cost to scheduling another operation immediately after the current operation on the same machine.

In this study, we do not consider the regulation depend setup times.

2.3. Previous Works on the Flowshop Scheduling problem

A number of studies on flowshop scheduling problem have been carried. The studies were carried out by applying various search method such constructive heuristics, search methods (i.e. Tabu Search (TS), and Local Improvement Procedure (LI)/Local

Search (LS), and enumeration. Johann Hurink and Jens Keuchel studies on Local Search Algorithms for a Single-Machine Scheduling Problem with Positive and Negative Time-Lags, point out positive and negative time-lags are general timing restrictions between the starting times of jobs which have been introduced in connection with the Metra Potential Method. Although very powerful, these relations have been rarely considered in the literature since for a single machine problem with positive and negative time-lags the problem of finding a feasible solution is *NP*-complete. In their paper, a local search approach for a single-machine scheduling problem with positive and negative time-lags and the objective to minimize the makespan is presented. Since the existence of a feasible initial solution for starting the search cannot be guaranteed, infeasible solutions are incorporated into the search process. Computational results based on instances resulting from shop problems are reported.

Edward L. Mooney and Ronald L. Rardin point out scheduling problems are often modeled as resource constrained problems in which critical resource assignments to tasks are known and the best assignment of resource time must be made subject to these constraints.

A research by Naveen Garg, Sachin Jain, and Chaitanya Swamy on randomized algorithm for flowshop scheduling state that the shop scheduling problems are known to be notoriously intractable, both in theory and practice. They also added the basic shop scheduling model consists of machines and jobs each of which consists of a set of operations. Each operation has an associated machine on which it has to be processed for a given length of time. The processing times of operations of a job cannot overlap. Each machine can process at most one operation at a given time. The algorithm developed based on the rounding of the solution of a Local Improvement (LI) formulation of the flowshop problem. The LI imposes some additional constraints which makes the rounding scheme possible.

In Netherlands, K.J. Batenburg and W.J. Palenstijn explored a New Exam Timetabling Algorithm. They state that the examination timetabling problem is a difficult combinatorial problem which has to be tackled several times a year by universities all over the world. The multi-stage algorithm introduced and appears to perform very well on various publicly available test datasets. They have analyzed an alternative multi-stage algorithm, based on modern AI (Artificial Intelligent) techniques such as evolutionary computation and tabu search. They also have showed that for large problems using a parallel variant of tabu search leads to significant improvements in the resulting timetable in comparison with the multi-stage algorithm. Although the new approach causes longer runtimes it can be parallelized very efficiently.

Keith Schmidt analyzed the implementation of a robust tabu search algorithm for the job shop scheduling problem and its extension to efficiently handle a broader class of problems, specifically Job Shop instances modeled with sequence dependent setup times. The Keith Schmidt studies focus on solving the job shop scheduling problem with sequence dependent setup times using Tabu Search. The Job Shop Scheduling problem is among the NP problems with the most practical usefulness. This problem is one of the most difficult NP-Hard problems to solve in practice.

The multi-stage parallel machine problem with limited buffer capacities studies conducted by Bagas Wardono and Yahya Fathi focus on the problem of scheduling N jobs on parallel machines in L successive stages with limited buffer capacities between stages. The target of the studies is to find a schedule that would minimize the makespan. A Tabu Search algorithm developed for this problem in which the search is limited to the space of permutation vectors of size N. This vector represented the order in which the given sets of jobs are performed in the first stage, and they proposed a procedure to construct a complete schedule associated with every permutation vector. The key feature of the algorithm is that it limits the search to the space of permutation vectors representing the order in which the given sets of jobs are processed in the first stage. They have developed several such procedures in the context of a tabu search algorithm for the problem with unlimited buffer capacities but these procedures applicable in the presence of limited buffer capacities. So they have constructed an effective constructive procedure for solving the problem.

Another research by Nysret Musliu on rotating workforce scheduling, is a typical constraint satisfaction problem which appears in a broad range of work places. In his studies, he used the combination of tabu search with random walk and minimum conflicts strategy to solve this problem. Computational results for benchmark showed that combination of tabu search with random walk and minimum conflicts strategy improves the performance of tabu search for this problem. The methods used improved performance of the state of art commercial system for generation of rotating workforce schedules.

CHAPTER III
SEARCH METHODS

In this chapter, we discuss the search procedures which are going to be implemented in this study. These procedures are namely Tabu Search procedure (TS) and Local Improvement procedure/Local Search (LI/LS), Genetic Algorithm (GA) and Simulated Annealing (SA).

3.1. TABU SEARCH

The Tabu search (TS) has been widely applied for solving combinatorial optimization problems. The basic concept of TS described by Glover (1986) is "a meta-heuristic superimposed on another heuristic". The meta-heuristic TS approach is dramatically changing our ability to solve problems of practical significance. The overall approach is to avoid entrainment in cycles by forbidding or penalizing moves which take the solution, in the next iteration, to point to the solution space previously visited. The TS is fairly new that Glover attributes it's origin to about 1977. The method is still actively researched that still continuing to evolve and improve. The TS method was partly motivated by the observation that human behavior appears to operate with a random element that leads to inconsistent behavior given similar circumstances.

The word *tabu* (or *taboo)* comes from Tongan, a language of Polynesia, where it was used by the aborigines of Tonga Island to indicate things that cannot be touched because they are sacred. According to Webster's Dictionary, the word tabu now also means "a prohibition imposed by social custom as a protective measure" or of something "banned as constituting a risk." These current more approaching senses of the word accord well with the theme of TS.

The roots of tabu search go back to the 1970's; it was first presented in its present form by Glover [Glover, 1986]; the basic ideas have also been sketched by Hansen [Hansen 1986]. Additional efforts of formalization are reported in [Glover, 1989], [de Werra & Hertz, 1989], [Glover, 1990]. Many computational experiments have shown that tabu search has now become an established optimization technique which can compete with almost all known techniques and which - by its flexibility - can beat many classical procedures. Up to now, there is no formal explanation of this good behavior. Recently, theoretical aspects of tabu search have been investigated [Faigle & Kern, 1992], [Glover, 1992], [Fox, 1993].

In TS, the algorithm begins with an initial solution which can be generated either randomly or using the result of a known the constructive procedure. The tabu search then improves the solution through a series of iteration. At each of the iteration, the tabu search then investigates the neighborhood of the current solution. The process repeated until it met the stopping criteria.

The application domain of the Tabu search has been traditionally on combinatorial optimization problems. The technique is straightforwardly applied to continuous functions by choosing a discrete encoding of the problem. The applications of TS are shown in table 3.1.

Table 3.1: Tabu Search (TS) applications.

1)	Scheduling	• Classroom Scheduling, Machine Scheduling, Flowshop, Job Shop Scheduling
2)	Telecommunications	• Call Routing, Bandwidth Packing, Optical Networks and Network Design.
3)	Design	• CAD, Transport Network Design, Architectural Space Planning, Fixed Charge Network Design
4)	Production, Inventory and Investment	• Flexible Manufacturing, Just-in-Time Production, Capacitated MRP, Part Selection
5)	Technology	• Electrical Power Distribution, Engineering Structural Design, Minimum Volume Ellipsoids
6)	Others	• Logic and Artificial Intelligence, Graph Optimization, Location and Allocation, Routing