

A META-HEURISTIC WEB-BASED OPTIMIZATION TOOL FOR ASSEMBLY
LINE BALANCING PROBLEMS

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Dedicated to...

*My beloved father and mother, Cheng Tiang Hooi and Ng Ah Lee,
Who has so much faith in me.
Love you always.*

*Also to my beloved sister and brothers
I could have never done it without you.*

*To all my friends, who have stood by me through thin and thick.
I treasure you all.*

*Thanks for showering me with love, support and encouragement.
Life has been wonderfully colored by you*

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ABSTRACT

Presently Assembly Line Balancing (ALB) problems are very common in many industrial systems and these problems are addressed based on an a set of assembly tasks assigned to an ordered sequence within the workstations. The purpose of this study is to investigate the use of heuristics and meta-heuristic in addressing Simple Assembly Line Balancing Problems (SALBP) and develop a web-based optimization tool based on heuristics and genetic algorithm (GA). This system was developed using Hypertext Preprocessor (PHP) and MySQL. The heuristic techniques used were longest operation time (LOT), largest candidate rule (LCR), and ranked positional weight (RPW). An improved fitness function based on the modified GA was proposed in this study as a means to avoid the problem of chromosome selection in classic GA and to find a faster ALB solution in an internet-enabled environment. The effect of improved fitness function and classic fitness function of modified GA on the performance of the developed web-based system was studied and the effectiveness and inadequacies of modified GA are presented. Comparison of the techniques will be determined and analysed based on the effectiveness of each techniques. The result of the standardised datasets indicated that the performance of the modified GA was superior compared to the other heuristic techniques based on the ALB results. In addition, the limitation of the web computation time for web-based optimization tool was also investigated. The results demonstrated that in most cases, the modified GA is able to produce ALB solution that can work within the limitation of the computation time. Furthermore, the system has been developed to benefit the industry by assigning a set of assembly tasks to workstations according to their main constraints as well as reducing the number of workstations needed.

ABSTRAK

Pada masa kini terdapat banyak masalah keseimbangan barisan pemasangan ditemui dalam kebanyakan sistem industri. Masalah ini ditangani berdasarkan satu set tugas yang ditugaskan dalam stesen kerja dengan urutan yang tersusun. Kajian ini dijalankan untuk mengkaji penggunaan heuristik dan meta-heuristik dalam masalah keseimbangan barisan pemasangan dan membangunkan sistem pengoptimuman berasaskan laman sesawang menggunakan heuristik dan GA. Perisian yang digunakan dalam pembangunan sistem ini adalah Hypertext Preprocessor (PHP) dan MySQL. Teknik heuristik yang digunakan untuk menyelesaikan SALBP adalah *longest operation time (LOT)*, *largest candidate rule (LCR)*, dan *ranked positional weigh (RPW)*. Dalam kajian ini, fungsi kesesuaian yang diperbaiki menggunakan kaedah algoritma genetik yang diubahsuai telah ketengahkan bagi mengelakkan masalah pemilihan kromosom dalam klasik GA dan mencari keputusan ALB yang lebih cepat dalam keadaan internet. Kesan penggunaan fungsi kesesuaian yang diperbaiki dan juga yang asal di dalam kaedah algoritma genetik yang telah diubahsuai diteliti berdasarkan prestasi sistem web yang dibangunkan, dan keberkesanan serta kekurangannya dikenalpasti. Perbandingan antara teknik-teknik ditentukan dan dianalisis berdasarkan kecekapan keempat-empat teknik ini. Dengan menggunakan bilangan set data yang setara, dalam kebanyakan kes didapati bahawa prestasi GA adalah lebih baik berbanding dengan heuristik lain dalam keputusan ALB yang dihasilkan. Di samping itu, had pengiraan jaringan masa yang dijanakan oleh sistem ini turut diteliti. Hasil keputusan ALB menunjukkan dalam kebanyakan kes, GA yang diubahsuai berkeupayaan menghasilkan keputusan yang terbaik dan memenuhi had pengiraan jaringan masa. Sistem yang dibangunkan ini dapat membantu pihak industri mangagihkan tugas kerja kepada stesen-stesen kerja berdasarkan kekangan keutamaan dan meminimumkan bilangan stesen kerja yang diperlukan.

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LIST OF ABBREVIATIONS

ACO	Ant Colony Optimization
ALB	Assembly Line Balancing
ALBP	Assembly Line Balancing Problems
ANN	Artificial Neural Networks
CPU	Central Processing Unit
ct	Cycle Time
DFD	Data Flow Diagram
E	Efficiency
GA	Genetic Algorithm
GALBP	Generalized Assembly Line Balancing Problems
ISO	International Organization for Standardization
LCR	Largest Candidate Rule
LOT	Longest Operation Time
MALBP	Mixed-model Assembly Line Balancing Problem
MOALBP	Multi-objective Assembly Line Balancing Problem
NP-hard	Non-deterministic Polynomial-time hard
PHP	Hypertext Preprocessor
RALBP	Robotic Assembly Line Balancing Problem
RAM	Random Access Memory
RPW	Ranked Positional Weight
SA	Simulated Annealing
SALBP	Simple Assembly Line Balancing Problems
SDLC	System Development Life Cycle
SQL	Structured Query Language

TS	Tabu Search
UALBP	U-Shaped Assembly Line Balancing Problem
WWW	World Wide Web

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Assembly lines are common in many production and manufacturing systems, particularly those entailing a large volume of a single product. They maximize the division of labour, thereby maximizing system productivity. Therefore, the configuration of the line and the distribution of work along the line are fundamental to the system's efficiency. A complex optimization problem arises when technological constraints and a given objective are also taken into account: the line balancing problem.

In an assembly line balancing problem (ALBP) a set of tasks have to be assigned to an ordered sequence of workstations in such a way that precedence constraints are maintained and a given efficiency measure is optimized. In the simplest case, referred to in the literature as SALBP: Simple Assembly Line Balancing Problems (e.g. Baybars 1986, Scholl and Becker 2006), a serial line

processes a single model of one product. Basically, the problem is restricted by technological precedence relations and the cycle time constrains.

In this research, we focus on SALBP-1 which is type-I of SALBP. In SALBP-1, the objective is to optimize the number of stations within a predetermined cycle time. Since this objective requires a number of stations, it can be seen as the counterpart of the previous one. The objective is equivalent to maximizing production rate.

Towards this, this research will discuss the design and development of a web-based ALB tool to solve ALBP on the Internet or intranet. With this web-based ALB tool, decision-makers, who may not know those sophisticated ALB methods very well, can remotely present and specify their ALBP. Based on the user input, the web-based ALB tool can suggest the best ALB solutions.

1.2 Problem Statement

Balancing assembly lines is an NP-hard problem arising frequently in manufacturing (Karp (1972), Garey and Johnson (1979)). Given a set of tasks to be processed, the basic problem consists in finding an assignment of tasks to workstations such that the total number of stations is minimized. The problem is constrained by a set of precedence relations between the tasks and by the cycle time, the given maximum available time per workstation. In recent years, various meta-heuristic algorithms have become popular for solving the scheduling problem, such as simulated annealing, neural networks, the ant colony algorithm, artificial immune systems, and the genetic algorithm (GA). Since then, many industries, and for sure researchers, attempt to find the best methods or techniques to keep the assembly line

balanced and even to make it more efficient. Furthermore, as there are many researches that have been performed, few techniques and methods have been used in solving the optimization problems. They are based on mathematical modeling, such as the use of linear programming, and then the latest are based on the meta-heuristic methods, with the more famous one being the use of genetic algorithms. Most of industrial manufacturer wanted flexible software to balance its lines as good as an experienced industrial engineer. However, most of their existing software which was developed by windows programming languages such as Pascal, C and Java is not longer supports technologies nowadays. Gradually, they always require change new technologies to help in their production. Therefore, we decided to develop our own software by developing combination algorithms in the web-based ALB tool. Besides, in this system, we emphasize the optimization of assembly line balancing by using heuristic methods and the meta-heuristic method which is the genetic algorithm (GA). Based on the problem statement, this research is come out with a problem namely: *“How can an optimization tool be developed that comprises both a heuristic and meta-heuristic methods?”*

1.3 Objectives

Based on the problem statements mentioned above, the three objectives of this research are identified as follows:

- (i) To implement a web-based assembly line balancing tool that includes heuristic and meta-heuristic methods.
- (ii) To implement GA with improved fitness function to find solution faster in the internet-enabled environment.
- (iii) To overcome the computation time under limited web execution time.

1.4 Scope

To ensure the project can achieve the objectives as stated; a few project scopes have been identified as follows:

- (i) Optimization of assembly line balancing using both heuristic methods and GA in web-based ALB tools.
- (ii) The optimization is carried out for only Simple Assembly Line Balancing Problems (SALBP).
- (iii) Using Hypertext Preprocessor (PHP) and MySQL to develop the web-based ALB tools.

1.5 Structure of the Thesis

This thesis consists of six chapters and is structured as follows:

Chapter 1 introduces the problems addressed in this thesis. This chapter also describes the general subject area, the objectives of the whole project implementation, and the scope which ensures the objectives stated can be achieved.

Chapter 2 presents the literature review. It discusses the main concepts related to assembly systems and gives an overview of the problems that have been addressed in previous studies, including the assembly line, ALB, heuristic methods, and meta-heuristic algorithms.

Chapter 3 is entitled Research Methodology. It discusses the methodology that is applied in system implementation and explains the measures made at every phase clearly and in detail. Furthermore, all needs from both hardware and software aspects will be listed.

Chapter 4 discusses implementation and testing and will explain the logical design and design system's physical form. In addition, aspects that are discussed include data analysis, system architecture, database design, interface design, and input and output specification. Furthermore, this chapter will also describe the codification and system testing.

Chapter 5 presents the results and evaluation of the Meta-heuristic Web-based Optimization Tool for ALBP. In this chapter, heuristic methods and GA will be used to solve the SALBP via the Internet using a web browser such as Internet Explorer or Mozilla Firefox. Furthermore, this chapter will also explain the analysis of the ALB result.

Finally, Chapter 6 presents the conclusions and further research proposals.

1.6 Contribution and Summary

This research is to provide new knowledge to implement a web-based ALB tool to solve real world problems more efficiently in the shortest possible time. In addition, this research also proposes a development of web-based assembly line balancing tools applying both heuristic methods and genetic algorithm (GA) methods to solve SALBP. Furthermore, the proposed genetic algorithm with a cutting point

and fitness function has also been improved in order to produce a better solution for ALB problems. This chapter starts from introduction, problem statement in ALB using heuristic and meta-heuristic methods. The objectives with the limitation of scope covered under this research have also been described. This is followed by structure of thesis. Finally, this research ends with the contribution and summary.

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