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

CHENG HUA WEI

UNIVERSITI TEKNOLOGI MALAYSIA

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

CHENG HUA WEI

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Master of Science (Computer Science)

Faculty of Computer Science & Information System
Universiti Teknologi Malaysia

February 2011

***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*

# ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my thesis supervisor, Dr. Ir. Muhammad Ikhwan Jambak, for his continuous support and guidance all the way until the completion of this thesis. His views, practical guidance and constructive comments were proven to be extremely valuable. Without his continued support and interest, this thesis would not have been the same as presented here.

Furthermore, I would also like to extend my appreciation to MOSTI for funding my Master study, Research Management Center who had managed it all. Librarians at Universiti Teknologi Malaysia also deserve special thanks for their assistance in supplying the relevant literatures.

Finally, special thanks to all the members of my family for their warm encouragement and love in carrying me through the challenging times throughout this study. I would like to acknowledge each person who has contributed to the success of this report, whether directly or indirectly.

# 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 tugasan 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 tugasan kerja kepada stesen-stesen kerja berdasarkan kekangan keutamaan dan meminimumkan bilangan stesen kerja yang diperlukan.

# TABLE OF CONTENTS

**2 LITERATURE REVIEW**

# LIST OF TABLES

# LIST OF FIGURES

# 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 |

# LIST OF APPENDICES

# 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 on 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.

# REFERENCES


Agpak, K. and Gokcen, H. (2005). Assembly line balancing: Two resource constrained cases. *International Journal of Production Economics*, 96: pp. 129–140.

Amen, M. (2000). Heuristic method for cost-oriented assembly line balancing: A survey, *International Journal of Production Economics*, 68(1): pp. 1-14.

Amen, M. (2001). Heuristic methods for cost–oriented assembly line balancing: A comparison on solution quality and computing time. *International Journal of Production Economics*, 69: pp. 255−264.

Anderson, E. J. and Ferris, M. C. (1993). *Genetic Algorithms for Combinatorial Optimization: The Assembly Line Balancing Problem*. University of Cambridge, Cambridge, England.

Bard, J. (1989). Assembly line balancing with parallel workstations and dead time. *International Journal of Production Research*, 27: pp. 1005−1018.

Bartholdi, J. (1993). Balancing two–sided assembly lines: A case study. International *Journal of Production Research*, 31: pp. 2447−2461.

Baybars, I. (1986). A survey of exact algorithms for the simple assembly line balancing problem. *Management Science*, 32: pp. 909−932.

Bittencourt, G. (2001). *Inteligência Artificial – Ferramentas e Teorias*. Editora da UFSC, Florianópolis, Brazil, 362 p.

Bowman, E. (1960). Assembly Line Balancing by Linear Programming. *Operations Research*, 8: pp. 385−389.

Boysen, N., Fliedner, M. and Scholl, A. (2007a). Assembly line balancing: Which model to use when?. *International Journal of Production Economics* (to appear, doi: 10.1016/j.ijpe.2007.02.026).

Boysen, N., Fliedner, M. and Scholl, A. (2007b). A classification of assembly line balancing problems. *European Journal of Operational Research*, 183: pp. 674−693.

Bricker, D. (1997). *Genetic Algorithm for Line Balancing*. University of Iowa, Iowa City, USA.

Chiang, W.C. (1998). The application of a tabu search metaheuristic to the assembly line balancing problem. *Annals of Operations Research*, 77, 209−227.

Dimitris V., Ioannis PL. Vlahavas. (2008). Artificial Intelligence for Advanced Problem Solving Techniques. *Information Science Reference, Hershey* - New York. Page 284.

Dolgui, A. (2006). Balancing Assembly and Transfer Lines. *European Journal of Operational Research*, 168: pp. 663−665.

Dorigo, M., Maniezzo, V. and Colorni, A. (1996). The Ant System: Optimization by a Colony of Cooperating Agents. *IEEE Transactions on Systems, Man and Cybernetics* - Part B, 26: pp. 29−41.

Erel, E. and Sarin, S. (1998). A survey of the assembly line balancing procedures. *Production Planning & Control*, 9: pp. 414−434.

Flake, G.W. (1999). The computacional beuty of Nature. Computer Explorations of Fractals, Chaos, Complex Systems and Adaptation. *The MIT Press*.

Garey M. R. and Johnson D. S. (1979). *Computer and Intractability: A Guide to the Theory if NP-Completeness*. WH Freeman: San Francisco.

Ghosh, S. and Gagnon, R. (1989). A comprehensive literature review and analysis of the design, balancing and scheduling of assembly systems. *International Journal of Production Research*, 27, 4, 637−670.

Glover, F. (1996). Tabu search and adaptive memory programming. Advances, applications and challenges. In R.S. Barr, R.V. Helgason, and J.L. Kennington (eds.). *Interfaces in Computer Science and Operations Research*, pp. 1-75. Kluwer.

Gottlieb, J., Puchta, M. and Solnon, C. (2003). A study of greedy, local search, and ant colony optimization approaches for car sequencing problems. Lecture Notes in Computer Science, *Springer*, 2611: pp. 246−257.

Hao, N. (2005). Sequencing and Balancing Problem of Mixed–Model–Assembly–Line with Window Cycle Time. Doctoral Thesis. UPC. Barcelona. Spain.

Helgeson, W. and Birnie, D. (1961). Assembly line balancing using the ranked positional weight technique. *Journal of Industrial Engineering*, 12: pp.394−398.

Hindman, C., Ousterhout, K.B. (1998). A virtual design system for sheet metal forming, *Journal of Material Processing Technology*, 84(1-3): pp.107-116.

Hoffman, T. R. (1990). Assembly line balancing - a set of challenging problems. *International Journal of Production Research* 28: pp. 1807-1815.

Hong, D. and Cho, H. (1999). A genetic–algorithm–based approach to the generation of robotic assembly sequences. *Control Eng. Practice*, 7: pp. 151−159.

Huang, G.Q., Nie, M., Mak, K.L. (1990) Web-based failure mode and effect analysis, *Computers and Industrial Engineering*, 37(1-2): pp.177-180.

JianXin, Jiao, Arun Kumar and Wilfried Martin (2005). A Web-based interactive adviser for assembly line balancing. *International Journal of Advanced Manufacturing Technology*, pp. 1-27. Singapore.

Karp R. M. (1972). Reducibility among combinatorial problems. *Complexity of Computer Computations*. Plenum Press: New York, pp 85-104.

Kilbridge M.D. and Wester.L (1961). A heuristic method of assembly line balancing. *Journal of Industrial Engineering*, 12(4): pp. 292-298.

Kim, Y.K., Kim Y.J. and Kim, Y. (1996). Genetic algorithms for assembly line balancing with various objectives. *Computers & Industrial Engineering*, 30: pp.397−409.

Lee, J. (2003). E-manufacturing systems: fundamental and tools, Robotics and *Computer-integrated manufacturing*, 9(6): pp.501-507.

Lee, Q. (2000). How to balance manufacturing work cell. *Institute of Industrial Engineers – IE Solutions Conference*,6: pp.21−23, Cleveland, Ohio.

Ling, Y.E., Lee, H.P., Cheok, B.T. (2002). Web-based metal forming advisory system for the finite element analysis of sheet metal bending, *Proceedings of The Institution of Mechanical Engineers, Part B-Journal of Engineering Manufacture*, 216(1): pp.39-45.

Martin, G.E. (1994). Optimal design of production lines. *International Journal of Production Research*, 32: pp.989−1000.

McMullen, P.R., Frazier, G.V, 1996. Assembly line balancing using simulation and data envelopment analysis, *Proceedings of Annual Meeting of the Decision Sciences Institute*, pp. 1391-1393, Orlando, FL.

Moyes, A., McArthur, S., Steele, J., Menal, J., McDonald, J., Devlin, J., McCabe, M. (1998). Gas circulator design advisory system – a Web based decision support system for nuclear power engineers, *IEE Colloquium (Digest)*, 307: pp.71-74.

Murata T., Ishibuchi H. and Tanaka H. (1996). Multi-objective genetic algorithm and its application to flowshop scheduling. *Computers and Industrial Engineering*, 30(4), pp. 957–968.

Niegemann, H.M. (2002). Developing a Web-based heuristic advisory system for instructional designer, *Proceedings of the International Conference on Computers in Education*, pp. 1352-1353, Auckland, New Zealand.

Osman, I.H. and Laporte, G. (1996). Metaheuristics: a bibliography. *Annals of Operations Research*, 63: pp. 513−623.

Patrick R. M. and Peter T. (2004). Using Ant Techniques to solve the Assembly Line Balancing Problem. *IIE Transactions* 35: pp. 605–617.

Patterson, J. and Albracht, J. (1975). Assembly Line Balancing: 0−1 Programming with Fibonacci Search. *Operations Research*, 23: pp. 166−174.

Pawadea R.S., Suhas S., and Brahmankar P.K.(2007). Effect of machining parameters and cutting edge geometry on surface integrity of high-speed turned Inconel 718 *International Journal of Machine Tools and Manufacture* doi:10.1016/j.ijmachtools.2007.08.004.

Pierreval, H., Caux, C., Paris, J. and Viguier, F. (2003). Evolutionary approaches to the design and organization of manufacturing systems. *Computers & Industrial Engineering*, 44: pp. 339−364.

Pinto, P., Dannenbring, D. and Khumawala, B. (1981). Branch and bound and heuristic procedures for assembly line balancing with paralleling of stations. *International Journal of Production Research*, 19: pp. 565−576.

Ponnambalam, S.G., Aravindan, P., Mogileeswar Naidu, G. (1999). A Comparative Evaluation of Assembly Line Balancing Heuristics, *International Journal of Advanced Manufacturing Technology*, 15: pp.577-586.

Reeves, C. (1993). Modern Heuristics Techniques for Combinatorial Problems. McGraw Hill.

Rekiek, B. (2001). *Assembly Line Design, multiple objective grouping genetic algorithm and the balancing of mixed–model hybrid assembly line*. Doctoral Thesis. Universite Libre de Bruxelles.

Rekiek, B., Dolgui, A., Delchambre, A. and Bratcu, A. (2002). State of art of optimization methods for assembly line design. *Annual Reviews in Control*, 26: pp. 163−174.

Rico L. and Díaz J. (2005). Surface roughness prediction la Rugosidad at 1018 cold rolled steel using Response Surface Methodology and neural networks. *Culcyt Research Year* 2 No.10.

Rubinovitz, J. and Bukchin, J. (1993). RALB – A heuristic algorithm for design and balancing of robotic assembly lines. Annals of the CIRP, 42: pp. 497−500.

Russell S. J. and Norvig P. (2003). Artificial Intelligence: A Modern Approach (2nd ed.). Upper Saddle River, NJ: Prentice Hall, pp. 111-114, *ISBN* 0- 13-790395-2.

Sabuncuoglu, I., Erel, E., & Tanyer, M. (2000). Assembly line balancing using genetic algorithms. *Journal of Intelligent Manufacturing*, 11(3): pp. 295–310.

Scholl A. (1993). Data of assembly line balancing problems. TH Darmstadt. Retrieved on November 1, 2009, from: http://www.assembly-line-balancing.de/

Scholl, A. and Voss, S. (1996). Simple assembly line balancing–Heuristic approaches. *Journal of Heuristics*, 2: pp. 217−244.

Scholl, A (1999). Balancing and Sequencing of Assembly Lines, Physica-Verlag.

Scholl, A. and Becker, C. (2006). State–of–the–art exact and heuristic solution procedures for simple assembly line balancing. *European Journal of Operational Research*, 168: pp. 666−693.

Suhaimi Ibrahim, Wan Mohd. Nasir Wan Kadir, Paridah Samsuri, Rozlina Mohamed dan Mohd Yazid Idris (1999). *Kejuruteraan Perisian*. Johor: Penerbit UTM. pp. 21-120.

Suresh, G. and Sahu, S. (1994). Stochastic assembly line balancing using simulated annealing. *International Journal of Production Research*, 32: pp. 1801−1810.

Thangavelu, S. and Shetty, C. (1971). Assembly Line by Zero–One Integer Programming. *AIIE Transactions*, 3: pp. 61−68.

Tian, G. Y., Yin, G., Taylor , D (2002). Internet-based manufacturing: A review and a new infrastructure for distributed intelligent manufacturing, *Jounrnal of Intelligent Manufacturing*, 13(5): pp. 323-338.

Tsai, D. and Yao, M. (1993). A line–balanced base capacity planning procedure for series–type robotic assembly line. *International Journal of Production Research*, 31: pp. 1901−1920.

Wang, Z. Y., Rajurkar, K. P., Kapoor, A. (1996). Architecture for agile manufacturing and it interface with computer integrated manufacturing, *Journal of Material Processing Technology*, 61(1-2): pp. 99-103.

Widmer M (1991). *Modèles mathématiques pour une gestion afficace des ateliers flexibles*. Presses Polytechniques et Universitaires Romandes: Lausanne.

White, W. (1961). Comments on a Paper by Bowman. *Operations Research*, 9: pp. 274−276.

Whitley L. W. (1994), A Genetic Algorithm Tutorial, Statistics and Computing, 4(2): pp. 65–85.

Yen, B. P.-C. (1997). Web based Simulation Tools, *Proceedings of International Conference on Industrial Engineering and Engineering Management*, August 18-22, Hong Kong.

Yen, B. P.-C. (1998). Agent-based Distributed Planning and Scheduling in Global Manufacturing, *Proceeding of the Annual International Conference on Industrial Engineering Theories, Application and Practice*, December 28-31, Hong Kong.