UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF SIMULTANEOUS SCHEDULING FOR MACHINES AND AUTOMATED GUIDED VEHICLES USING FUZZY GENETIC ALGORITHM

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OPTIMIZATION OF SIMULTANEOUS SCHEDULING FOR MACHINES AND AUTOMATED GUIDED VEHICLES USING FUZZY GENETIC ALGORITHM

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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UPM

DEDICATION

I dedicate this thesis to my parents who support me during my studies

Abstract of thesis to be presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

OPTIMIZATION OF SIMULTANEOUS SCHEDULING FOR MACHINES AND AUTOMATED GUIDED VEHICLES USING FUZZY GENETIC ALGORITHM

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JUNE 2009

Chairman: **Professor Shamsuddin bin Sulaiman, PhD**

Faculty: **Engineering**

Flexible manufacturing system (FMS) has been introduced by the researchers as an integrated manufacturing environment. Automated guided vehicles (AGVs) introduced as the main tool of material handling systems in FMS. While the scheduling of AGVs and machines are highly related; simultaneous scheduling of machines and AGVs has been proposed in the literature. Genetic algorithm (GA) proposed as a robust tool for optimization of scheduling problems. Setting the proper crossover and mutation rates are of vital importance for the performance of the GA. Fuzzy logic controllers (FLCs) have been used in the literature to control key parameters of the GA which is addressed as fuzzy GA (FGA). A new application of FGA method in simultaneous scheduling of AGVs and machines is presented. The general GA is modified for the aforementioned application; more over an FLC is developed to control mutation and crossover rates of the GA. The objective of proposed FGA method is to minimize the makespan, production completion time of

all jobs that they are produced simultaneously. An optimal sequence of operations is obtained by GA. There is a heuristic algorithm to assign the AGVs to the operations. As the main findings, the performance of GA in simultaneous scheduling of AGVs and machines is enhanced by using proposed method, furthermore a new mutation operator has been proposed. Several experiments have been done to the proposed test cases. The results showed that tournament selection scheme may outperform roulette wheel in this problem. Various combinations of population size and number of generations are compared to each other in terms of their objective function. In large scale problems FGA method may outperforms GA method, while in small and medium problems they have the same performance. The fluctuation of obtained makespan in FGA method is less than GA method which means that it is more probable to find a better solution by FGA rather than GA.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGOPTIMUMAN PENJADUALAN MESIN-MESIN DAN KENDERAAN BERPANDU BERAUTOMOTIK SECARA SERENTAK MENGGUNAKAN PENGAWAL LOGIK SAMAR

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MOSTAFA BADAKHSHIAN

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Pengerusi : Profesor Shamsuddin bin Sulaiman, PhD

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Sistem pembuatan fleksibel (FMS) telah diperkenalkan oleh tenaga penyelidik sebagai satu persekitaran pembuatan bersepadu. Kenderaan berpandu berautomatik (AGVs) diperkenalkan sebagai perkakas utama untuk sistem pengendalian bahan di FMS. Manakala penjadualan AGVs dan mesin adalah amat berkaitan; penjadualan serentak mesin dan AGVs telah disarankan didalam kajian ilmiah. Algoritma genetik (GA) telah dicadangkan sebagai satu alat teguh untuk pengoptimuman masalah penjadualan. Menyediaan lintasan dan kadar-kadar mutasi yang tersusun adalah amat penting untuk prestasi GA. Alat-alat kawalan logik samar (FLCs) telah digunakan dalam kajian ilmiah untuk parameter kekunci kawalan GA yang dikenali sebagai samar GA (FGA). Satu penggunaan yang baru bagi kaedah FGA didalam penjadualan serentak AGVs dan mesin-mesin telah dibentangkan. GA yang secara umum telah diubahsuai untuk penggunaan sebelumnya terutamanya untuk FLC yang dibangunkan untuk mengawal mutasi dan kadar-kadar lintasan GA. Objektif kaedah yang dicadangkan adalah bagi meminimumkan makespan, masa siap produksi bagi

semua pekerjaan telah dihasilkan secara serentak. Satu urutan optimum operasi-operasi adalah diperolehi melalui GA. Terdapat satu algoritma heuristik untuk menentukan AGVs ke operasi. Sebagai penemuan yang utama, prestasi bagi GA didalam penjadualan serentak AGVs dan mesin-mesin telah ditingkatkan dengan menggunakan kaedah yang dicadangkan, tambahan pula satu pengendali mutasi yang baru telah dicadangkan. Beberapa eksperimen yang dicadangkan telah dilaksanakan bagi menguji kes-kes. Keputusan menunjukkan bahawa skim pemilihan *tournament* mungkin mengatasi *roulette wheel* dalam masalah ini. Gabungan-gabungan pelbagai saiz populasi dan jumlah generasi dibandingkan antara satu sama lain dalam fungsi objektif mereka. Dalam permasalahan yang berskala besar, kaedah FGA mungkin mengatasi kaedah GA, sementara dalam permasalahan kecil dan sederhana, pretasi yang ditunjukkan adalah sama . Perubahan yang diperolehi dari *makespan* didalam kaedah FGA adalah berkurangan dari kaedah GA yang bermaksud ia adalah mungkin lebih baik bagi mencari satu penyelesaian menggunakan FGA dari GA.

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In the name of Allah, Most Gracious, Most Merciful. Praise be to Allah, the Cherisher and Sustainer of the worlds; Most Gracious, Most Merciful; Master of the Day of Judgment. Thee do we worship, and Thine aid we seek. Show us the straight way, The way of those on whom Thou hast bestowed Thy Grace, those whose (portion) is not wrath, and who go not astray. (Holly Quraan; The Opening)

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I certify that a Thesis Examination Committee has met on 22nd June 2009 to conduct the final examination of Mostafa Badakhshian on his thesis entitled "optimization of simultaneous scheduling for machines and automated guided vehicles using fuzzy genetic algorithm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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Date: 11 September 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

MOSTAFA BADAKHSHIAN

Date: 10 October 2009

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LIST OF ABBREVIATIONS

Abbreviation	Description
AGA	Adopted Genetic Algorithm
AGV	Automated Guided Vehicle
AGVS	Automated Guided Vehicle System
BV	Best Values
CR	Crossover Rate
EA	Evolutionary Algorithm
EEX	Enhanced Edge Crossover
FBV	Frequency of Best Value
FGA	Fuzzy Genetic Algorithm
FLC	Fuzzy Logic Controller
FMS	Flexible Manufacturing System
GA	Genetic Algorithm
GAT	Genetic Algorithm by Tournament
GARW	Genetic Algorithm by Roulette Wheel
GDP	Gross Domestic Production
GPDP	General Pick-up and Delivery Problem
MF	Membership Function
MR	Mutation Rate
NC	Numerically Controlled
OBX	Order-Based Crossover
OX	Order Crossover
PBX	Position-Based Crossover
PDPTW	Pick-up and Delivery Problem with Time Windows
PMX	Partially-Mapped Crossover
RB	Rule Base
UX	Union Crossover

CHAPTER ONE

INTRODUCTION

1.1 Flexible Manufacturing System

Manufacturing industries in most of the developed and developing countries have an important role in the economy. Manufacturing industries produced 15 to 30% gross domestic production (GDP) in these countries is produced, which are one of the few ways for creating wealth (Mok, 2001). Ever increasing customers' demands for better quality and lower prices forced the companies to improve their products or services. During recent years the life cycle of the products has shortened, market intentions changed quickly, and technology improved day by day. The aforementioned factors forced the manufacturing organizations to improve their performance and, if one company neglects of improving itself, there are many other companies to do it, and increase their market share. The manufacturing performance is no longer driven by the product price; instead other competitive factors such as flexibility, quality, and delivery have become equally important (Chan and Swarnkar 2006). Hence, the manufacturers would prefer to use such kind of production technology in which changes can be made as low costly as possible and in minimum of possible time.

According to Raj et al. (2007) a flexible manufacturing system (FMS) is an integrated, computer-controlled complex arrangement of automated material handling devices and numerically controlled (NC) machine tools. FMS can simultaneously process medium-sized volumes of a variety of part types. FMS is

capable of producing a variety of part types and handling flexible routing of parts instead of running parts in a straight line through machines (Chen and Ho 2005). Issues related to implementation of FMS are regarding loading of parts; scheduling techniques; material handling; flexibility and its measurement; machine tools; operation, control and maintenance techniques; and human element and culture (Raj et al., 2007).

FMS is a complex system consisting of elements like workstations, automated storage and retrieval systems, and material handling devices such as robots and automated guided vehicle (AGVs). AGVs are battery-powered driverless vehicles, centrally computer-controlled and independently addressable. They move either along wire guidepaths (flowpaths), or by magnetic or optic guidance (Ganesharajah et al., 1998). They are used to move jobs between workstations on a factory floor. Vehicle positioning, battery management, vehicle requirement or fleet sizing, pick up and delivery points, flowpath design, vehicle routing and deadlock resolution, traffic management, vehicle dispatching, and vehicle scheduling are propounded for AGV systems problems (Le-Anh and Koster, 2006).

1.2 AGV Scheduling

Scheduling is concerned with the allocation of limited resources to tasks overtime and is a decision making process that links the operations, time and overall objectives of the company. Scheduling of machines and other resources such as vehicles, personnel, tools etc. has been done with a certain objective, to be either minimized or maximized. The objectives include minimization of makespan at first

and after that include minimization tardiness, earliness, in process inventory. The FMS elements can operate in an asynchronous manner and the scheduling problems are more complex. Moreover the components are highly interrelated and in addition contain multiple part types, and alternative routings etc. FMS performance can be increased by better co-ordination and scheduling of production machines and material handling equipment (Reddy and Rao, 2006).

Typically parts in a manufacturing system visit different machines for different operations, and they thus generate demand for the material handling devices. Scheduling of the material handling system in FMS has equal importance as of machines and is to be considered together for the actual evaluation of cycle times. Because of wildly use of AGVs in FMS environments due to their flexibility and compatibility, AGVs cannot be neglected while scheduling the production tasks and it is necessary to take into account interaction between machines, AGVs and computers.

The vehicle scheduling system decides when, where and how a vehicle should act to perform tasks, including the routes it should take. If all tasks are known prior to the planning period, the scheduling problem can be solved offline (Le-Anh and Koster, 2006). Both the scheduling of operations on machine centers as well as the scheduling of AGVs are essential factors contributing to the efficiency of the overall FMS. An increase in the performance of the FMS under consideration would be expected as a result of making the scheduling of AGVs and machine scheduling simultaneously is integral part of the overall scheduling activity. Simultaneous machine and material handling scheduling problem in FMS environment is solved by

authors recently like, Ulusoy et al. (1997), Anwar and Nagi (1998), Abdelmaguid et al. (2004), and Lacomme et al. (2005) and Reddy and Rao (2006).

1.3 Problem Statement

As mentioned in section 1.2, the simultaneous scheduling of AGVs and machines in FMS environments has been widely regarded in the literatures. In this kind of problem a sequence of desired tasks are considered to be completed on various machines of FMS. AGVs are scheduled in a way that total traveling time of AGVs and operational time of machines is minimized. Many of the literatures proposed mathematical formulations to solve this problem (Bilge and Ulusoy, 1995; Jawahar et al., 1998, El Khayat, 2006). Incidentally most of the literatures showed that genetic algorithms (GAs) can be considered as an optimization tool to improve the performance of the results of such kind of problem (Ulusoy et al., 1997, Abdelmaguid et al., 2004; Reddy and Rao, 2006).

In a recent research Jerald et al. (2006) proposed an adaptive GA (AGA) to improve the performance of GA in optimization of simultaneous scheduling of AGVs and parts. They used some expert rules to adapt the parameters of the GA during its running. They concluded that the proposed AGA showed better results than conventional GA with constant parameters. Based on the reviewed literatures, the performance of genetic algorithm is highly depends on the accuracy of its parameter which need to be set by the designer. Brito et al. (2006) mentioned that fuzzy logic controllers (FLCs) can be used to enhance the performance of GAs. The proposed method is addressed as fuzzy genetic algorithm (FGA) (Herrera and Lozano, 2003).

Hence, based on the reviewed literature, the FGA method has not been applied in simultaneous scheduling AGVs and machines. Hence an FLC can be developed to control the key parameters of genetic algorithm to optimize simultaneous scheduling of AGVs and machines. Moreover the major operators of genetic algorithm can be modified due to characteristics of the scheduling problems in order to enhance the performance of the GA.

1.4 Objectives of the Thesis

The final goal of this research is to develop a fuzzy genetic algorithm method to schedule the AGVs and machines simultaneously in an FMS environment. This is done through designing fuzzy logic controller module, genetic algorithm module and FMS scheduling module. Based on the stated problem the following objectives are considered for this thesis:

(1) To modify the existing genetic algorithm for the scheduling of AGVs and machines, simultaneously.

(2) To develop a fuzzy logic controller module to control the parameters of the proposed GA during its process time.

(3) To evaluate the performance of the proposed method (FGA) against the same results of conventional GA for designed test cases in term of their objective functions.

1.5 Scope of Thesis and Limitations

All kind of the FMS environments can be regarded as the scope of the proposed method. The results of the proposed methodology are only examined through

computer based simulation of the FMS environments. Among all the required parameters of the AGV and machines only the scheduling of these two components of FMSs is considered. The other vital parameters such as routing policies, dispatching rules, and layout are selected based on the past literatures. The author believes that the proposed method can be used in any other FMS-based application with minor modification, only and if only the same conditions are considered by the modeler for the future application. The proposed fuzzy logic controller is driven out from the work of Brito et al. (2006). Modifications have been performed by the author where it is needed.

1.6 Organization of Thesis

As mentioned in previous sections, the thesis has been organized in order to present a background of AGV scheduling in FMS environments. Chapter one to chapter five of this thesis, are responsible to perform this. Chapter one provides a general introduction for different components of the thesis. Flexible manufacturing systems, AGV and machine scheduling, fuzzy genetic algorithm, the main problem of the thesis, objectives followed by current research, and finally scopes and limitations of this thesis are introduced in this chapter.

Chapter two reviews the most important literatures on AGVs and FMS scheduling problem. Especially the simultaneous scheduling of AGVs and machines are considered in this chapter. Genetic algorithms and their optimization method in scheduling problems, fuzzy logic controllers (FLCs) and their designing process, the application of FLCs to control the parameters of GAs are reviewed in this chapter.

Chapter three describes the methodology which used in this thesis. Details on the proposed scheduling algorithm for simultaneous scheduling of AGVs and machines are reported in this chapter. The proposed genetic algorithm and its main operators are described in next. Proposed FLC module, details on the input and output variables, their membership function, and fuzzy rule base are described briefly in this chapter. The designed test cases are reviewed in this chapter finally.

Chapter four is devoted to results of the experiments of application of FGA method in the scheduling of the proposed test case. The results of these experiments are compared to the results of the AGV and machine scheduling using conventional GA method. The obtained results are discussed well at the end of this chapter. In last chapter of the current thesis chapter five summarizes the overall contents of this thesis. Conclusions and recommendations for further research in this compass are noted finally.