UNIVERSITI PUTRA MALAYSIA

OPTIMIZATION OF FUZZY LOGIC CONTROLLERS WITH GENETIC ALGORITHM FOR TWO-PART-TYPE AND RE-ENTRANT PRODUCTION SYSTEMS

SEYED MAHDI HOMAYOUNI

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By

SEYED MAHDI HOMAYOUNI

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

November 2007

DEDICATION

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

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

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November 2007

Chairman: Tang Sai Hong, PhD

Faculty: Engineering

Improvement in the performance of production control systems is so important that many of past studies were dedicated to this problem. The applicability of fuzzy logic controllers (FLCs) in production control systems has been shown in the past literature. Furthermore, genetic algorithm (GA) has been used to optimize the FLCs performance. This is addressed as genetic fuzzy logic controller (GFLC). The GFLC methodology is used to develop two production control architectures named "genetic distributed fuzzy" (GDF), and "genetic supervisory fuzzy" (GSF) controllers. These control architectures have been applied to single-part-type production systems. In their new application, the GDF and GSF controllers are developed to control multi-part-type and re-entrant production systems. In multi-part-type and re-entrant production systems the priority of production as well as the production rate for each part type is determined by production control systems. A genetic algorithm is developed to tune the membership functions (MFs) of input variables of GDF and

GSF controllers. The objective function of the GSF controller is to minimize the overall production cost based on work-in-process (WIP) and backlog cost, while surplus minimization is considered in GDF controller. The GA module is programmed in *MATLAB*® software. The performance of each GDF or GSF controllers in controlling the production system model is evaluated using *Simulink*® software. The performance indices are used as chromosomes ranking criteria. The optimized GDF and GSF can be used in real implementations. GDF and GSF controllers are evaluated for two test cases namely "two-part-type production line" and "re-entrant production system". The results have been compared with two heuristic controllers namely "heuristic distributed fuzzy" (HDF) and "heuristic supervisory fuzzy" (HSF) controllers. The results showed that GDF and GSF controllers can improve the performance of production system. In GSF control architecture, WIP level is 30% decreased rather than HSF controllers. Moreover the overall production cost is reduced in most of the test cases by 30%. GDF controllers show their abilities in reducing the backlog level but generally production cost for GDF controller is greater than GSF controller.

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

PENGOPTIMUMAN PENGAWAL LOGIK SAMAR DENGAN ALGORITMA GENETIK UNTUK SISTEM PENGELUARAN JENIS-DWI-BAHAGIAN DAN MASUK-SEMULA

Oleh

SEYED MAHDI HOMAYOUNI

November 2007

Pengerusi: **Tang Sai Hong, PhD**

Fakulti: **Kejuruteraan**

Penambahbaikan sistem kawalan pengeluaran begitu penting sehingga banyak bahan kajian lepas ditumpukan kepada masalah ini. Tambahan pula ia telah menunjukkan bahawa kawalan sistem pengeluaran dengan menggunakan pengawal samar logik (FLC) boleh mengatasi prestasi arkitek kawalan lain. Selain itu, genetik algoritma (GA) telah digunakan untuk mengoptimumkan prestasi FLC. Ini dikenal pasti sebagai pengawal genetik samar logik (GFLC). Dalam tesis ini, metodologi GFLC digunakan untuk membangunkan dua arkitek kawalan pengeluaran yang dinamakan pengawal "samar genetik tersebar" (GDF), dan "samar penyeliaan genetik" (GSF). Sebelum ini, arkitek kawalan ini digunakan untuk sistem pengeluaran jenis bahagian tunggal. Tetapi dalam pendekatan baharu, pengawal GDF dan GSF dibangunkan untuk mengawal sistem pengeluaran kompleks. Metodologi ini dijelaskan dan dinilai dengan menggunakan dua kajian kes; iaitu talian pengeluaran jenis dua bahagian dan sistem rangkaian pengeluaran masuk semula. Untuk pengawal jenis ini, GA digunakan untuk menalakan fungsi keahlian (MF) FLC. Fungsi objektif pengawal

GSF adalah untuk meminimumkan kos pengeluaran secara keseluruhan berdasarkan kerja dalam proses (WIP) dan kos log balik, sementara peminimuman berlebihan dipertimbangkan dalam pengawal GDF. Modul GA diprogramkan dalam perisian *MATLAB*®. Prestasi setiap FLC dalam mengawal model sistem pengeluaran dinilai menggunakan *Simulink*®. Indeks prestasi digunakan sebagai kriteria pemeringkatan kromosom. GDF atau GSF yang dioptimumkan boleh digunakan dalam pelaksanaan sebenar. Dapatannya menunjukkan bahawa pengawal GDF dan GSF dapat menambah baik prestasi sistem pengeluaran. Dalam arkitek kawalan GSF, paras WIP berkurang 30% berbanding dengan pengawal HSF. Tambahan pula, kos pengeluaran keseluruhan dikurangkan sebanyak 30% dalam kebanyakan kes ujian. Pengawal GDF menunjukkan keupayaannya dalam mengurangkan paras log balik tetapi secara umumnya kos pengeluaran bagi pengawal GDF adalah lebih tinggi berbanding dengan pengawal GSF.

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Allah, the dominion of the heavens and the earth belongs to him. No son has he been gotten nor has he a partner in his dominion. It is he who created all things and ordered them in due proportions (Holly Quraan 25:2)

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Your nice help, I would never forget.

I certify that an Examination Committee met on 21st November 2007 to conduct the final examination of Seyed Mahdi Homayouni on his Master degree thesis entitled "optimization of fuzzy logic controllers with genetic algorithm for two-part-type and re-entrant production systems" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the student be awarded the relevant degree. Members of the Examination Committee were as follows:

Megat Mohamad Hamdan Megat Ahmad, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Wong Shaw Voon, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Faieza Abdul Aziz, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Awaluddin Mohamed Shahraoun, PhD
Professor
Faculty of Engineering
Universiti Technology Malaysia
(External Examiner)

____

HASNAH MOHD. GHAZALI, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Tang Sai Hong, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Napsiah Ismail, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 February 2008

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.

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SEYED MAHDI HOMAYOUNI

Date: 20 July 2008

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LIST OF ABBREVIATIONS

Abbreviation	Description
AGV	Automated Guided Vehicle
$\overline{\textbf{BL}}$	Mean Backlog
DB	Data Base
DBL	Downstream Buffer Level
DEM	Demand
DMP	Downstream Machine Production
DVWIP	Work In Process Error
EA	Evolutionary Algorithm
EDD	Earliest Due Date
EDF	Evolutionary Distributed Fuzzy
EP	Evolutionary Programming
ES	Evolutionary Strategies
ESF	Evolutionary Supervisory Fuzzy
FLC	Fuzzy Logic Controller
FPR	Fuzzy Production Rate
FSC	Fuzzy Surplus Correction
FSCF	Fuzzy Surplus Correction Factors
FSRP	Final Product Surplus
GA	Genetic Algorithm
GDF	Genetic Distributed Fuzzy
GDP	Gross Domestic Production

GFLC	Genetic Fuzzy Logic Controller
GFS	Genetic Fuzzy System
GSF	Genetic Supervisory Fuzzy
HDF	Heuristic Distributed Fuzzy
HGFS	Hierarchy Genetic Fuzzy System
HSF	Heuristic Supervisory Fuzzy
IBL	Initial Buffer Level
JIT	Just In Time
KB	Knowledge Base
MAPP	Multi-product Aggregate Production Planning
MBCKLG	Mean Backlog
MF	Membership Function
MFSRP	Mean Final Surplus
MRP	Material Requirements Planning
PR	Production Rate
RB	Rule Base
SRP	Surplus
UBL	Upstream Buffer Level
$\overline{\mathbf{WIP}}$	Mean Work In Process
WIP	Work In Process

CHAPTER 1

INTRODUCTION

1.1 Manufacturing Systems

The word “manufacturing” derives from two Latin word roots meaning “hand” and “make” (Harrington, 1984). Manufacturing is the act of converting raw materials into desired final products. Materials, labor, technology and capital are required to make the products (Mok, 2001). Desired products (with specific characteristics) and wastes are the outputs of manufacturing systems. A set of decisions are made at various levels of the manufacturing, to smooth the production processes, stabilizing the production rate and maintain the quality of final product.

There is a set of disturbances which lead every manufacturing system into instability. Demand and market fluctuations, competition, equipment failures, government policies and labor problems are some of these disturbances (Viswanadham, 1999). So predicting the future of manufacturing systems and planning for different related requirements (such as raw material, production rate, developing new products and etc.) is too difficult due to its instability. Globalization, higher customers’ awareness, volatility of consumer preferences, new communication gate ways and global competition forced manufacturing to decrease the wastes and increase their performances. These reasons made manufacturing scheduling a complex function. Customers are seeking for lower prices and better qualities, even zero defects. In this situation if one company neglects improving itself, there are lots of competitors to do it, and increase their market share.

Manufacturing industries in most of the developed and developing countries have a brilliant role in the economy. Fifteen to thirty percent of gross domestic production (GDP) in these countries is produced by manufacturing industries, which are one of the few ways for creating wealth (Mok, 2001). Due to the important role of manufacturing systems, many of the literatures in the field of industrial engineering and production management introduced new approaches to improve performance of manufacturing systems. Some of the most important techniques and technologies introduced through past decades are: flexible manufacturing systems (Rezaie and Ostadi, 2007), group technology (Andres *et al.*, 2005), just-in-time (Polito and Watson, 2006), lean manufacturing (Holweg, 2007), and mass customization (Duray *et al.*, 2000 and Silveira *et al.*, 2001).

1.2 Production Control

Manufacturing systems consists of several functions and modules. These modules include: procurement department, information technology department, business department, financial management and the most important one, production department (Mok, 2001). The production function is the set of activities directly involved in the physical handling and converting of raw materials into finished products in accordance with designs received from the development department and with directives from the management function.

The focal point in the conversion of materials into finished products is production control. The production control of manufacturing systems is at the heart of the whole manufacturing process. A set of on time decisions for various production states should be made by control systems. Improving the effectiveness of production control systems cause improvement in the scheduling of production systems. Production scheduling manages the flow of materials or components through the manufacturing system (Tsourveloudis *et al.*, 2007). Too many theories and control architectures were introduced in past decades. According to Gershwin (2000) “Time-based”, “token-based” and “surplus-based” methods are three main classifications of control policies (these policies are briefly introduced in chapter two, section 2.5).

The procedure of control system is quite simple. The system state is mapped onto a set of possible control actions. State variables define the system state. These variables determine the overall specifications of the manufacturing system in each time period. This information consists of number of part types, inventories in hand, and the status of a machine and so on. Control actions are responsible to change the system state in order to satisfy the overall goal of system.

To construct a control system, three things need to be identified: the system state, the possible control actions, and the mapping between the system state and the control actions. Through these system specifications, the method of mapping the system state to control action usually has been created on human observation and experience basis (Passino and Yurkovic, 1998). To transform this human knowledge to an automated control system, one may use rule-based control system. Rules are of the form: IF a set of conditions THEN perform these control actions. If the first phrase is true then the second statement is implemented to make decisions.

The major problem arises with rule-based control is the difficulty in developing good rules. One of the most used kinds of rule-based controllers is fuzzy logic controllers (FLCs) (Mamdani, 1977; Passino and Yurkovic, 1998 and Pedrycz, 1995). FLCs use heuristic information to make their rule base and membership functions. Such heuristic information may come from an operator who acts as a "human-in-the-loop" controller for a process. In fact, FLCs emulate the decision-making process of the operator (Passino and Yurkovic, 1998). Optimal design of the FLC knowledge base (membership functions and rule base) is central to the performance of the FLC. The rule base reflects the human expert's knowledge expressed as linguistic variables, while the membership functions represent expert interpretation of those same variables.

In the absence of such knowledge, commonly trial and error is used to reach the desired performance of system. If the number of decision variables or system status is too large, this approach is not practical. In this case tuning or learning process is more useful. Genetic algorithm (GA) is one of the tools in learning process (Gen and Cheng, 1997; Haupt and Haupt, 2004). GAs are robust, numerical search methods that mimic the process of natural selection. Parameters of fuzzy membership functions are used to make chromosomes for GAs. The fittest chromosomes based on performance of FLC are chosen to mate a new generation. Crossover and mutation operators are used to make offspring. The new population consists of offspring and parents. This population is evaluated in next cycle of algorithm. The algorithm stops after a pre-defined number of generations or convergence of performance indices of chromosomes. This process is called genetic fuzzy logic controller (GFLC) (Cordon *et al.*, 2004; Velasco and Magdalena, 1995 and Mattelan *et al.*, 1998).

In multi-part-type production system more than one part type can be processed. In re-entrant production systems one part type is processed more than one time by a specific machine. Controlling these production systems is proven to be difficult (Srivatsan and Dallery, 1998). Controllers should consider the priority of production of part types and set the proper production rate for each part type. In this thesis, control is the set of activities determining the detailed allocation of available resources to particular tasks for the immediate time period at hand.

1.3 Problem Statement

As mentioned in the previous section (1.2), production control system is vital for companies, and the performance of control system is so important that many of researches in the field of production management has been dedicated to this subject. Heuristic distributed fuzzy (HDF) controller (Tsourveloudis *et al.*, 2000) was proposed to control the production systems based on local data for each machine. This control architecture has been applied to single-part-type and multi-part-type production systems. Ioannidis *et al.* (2004) proposed heuristic supervisory fuzzy (HSF) controllers where it can be used to improve performance of HDF controllers. Multi-part-type production line and re-entrant production network, single-part-type production line and network, were examined with supervisory fuzzy controller Tsourveloudis *et al.* (2005, 2006 and 2007) used GFLSc to optimize the performance of supervisory and distributed fuzzy controllers. Genetic supervisory fuzzy (GSF) controller and genetic distributed fuzzy (GDF) controller were introduced by them. Tsourveloudis *et al.* (2005, 2006 and 2007) used their new approach to control a single-part-type production line and network.