**UNIVERSITI PUTRA MALAYSIA**

# PROCESS PLANNING OPTIMIZATION IN RECONFIGURABLE MANUFACTURING SYSTEMS

**FARAYI MUSHARAVATI**

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# PROCESS PLANNING OPTIMIZATION
# IN
# RECONFIGURABLE MANUFACTURING SYSTEMS

**By**

**FARAYI MUSHARAVATI**

**Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy**

**May 2008**

**DEDICATION**

To

**All My Friends**

There is a time for all things: a time for shouting, a time for gentle speaking, a time for silence, a time for washing pots and a time for writing journal papers and books. It is hard to make a **BEGINNING**, and will become harder, but **IT MUST BE DONE**. So be vigilant and vigorous for that will cover a *"multitude of sins"*. And do not frown. And remember: "work banishes those three great evils: *boredom*, *vice* and *poverty*"

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

**PROCESS PLANNING OPTIMIZATION IN RECONFIGURABLE MANUFACTURING SYSTEMS**

By

**FARAYI MUSHARAVATI**

**May 2008**

**Chairman: Associate Professor Napsiah Ismail, PhD**

**Faculty: Engineering**

Trends and perspectives in dynamic environments point towards a need for optimal operating levels in reconfigurable manufacturing activities. Central to the goal of meeting this need is the issue of appropriate techniques for manufacturing process planning optimization in reconfigurable manufacturing, i.e. (i) what decision making models and (ii) what computational techniques, provide an optimal manufacturing process planning solution in a multidimensional decision variables space? Conventional optimization techniques are not robust, hence; they are not suitable for handling multidimensional search spaces. On the other hand, process planning optimization for reconfigurable manufacturing is not amenable to classical modeling approaches due to the presence of complex system dynamics. Therefore, this study explores how to model reconfigurable manufacturing activities in an optimization perspective and how to develop and select appropriate non-conventional optimization techniques for reconfigurable process planning.

In this study, a new approach to modeling Manufacturing Process Planning Optimization (MPPO) was developed by extending the concept of manufacturing optimization through a decoupled optimization method. The uniqueness of this approach lies in embedding an integrated scheduling function into a partially integrated process planning function in order to exploit the strategic potentials of flexibility and reconfigurability in manufacturing systems. Alternative MPPO models were constructed and variances associated with their utilization analyzed. Five (5) Alternative Algorithm Design Techniques (AADTs) were developed and investigated for suitability in providing process planning solutions suitable for reconfigurable manufacturing. The five (5) AADTs include; a variant of the simulated annealing algorithm that implements heuristic knowledge at critical decision points, two (2) cooperative search schemes based on a "loose hybridization" of the Boltzmann Machine algorithm with (i) simulated annealing, and (ii) genetic algorithm search techniques, and two (2) modified genetic algorithms.

The comparative performances of the developed AADTs when tasked to solve an instance of a MPPO problem were analyzed and evaluated. In particular, the relative performances of the novel variant of simulated annealing in comparison to: (a) (i) a simulated annealing search, and (ii) a genetic search in the Boltzmann Machine Architecture, and (b) (i) a modified genetic algorithm and (ii) a genetic algorithm with a customized threshold operator that implements an innovative extension of the diversity control mechanism to gene and genome levels; were pursued in this thesis.

Results show that all five (5) AADTs are capable of stable and asymptotic convergence to near optimal solutions in real time. Analysis indicates that the performances of the implemented variant of simulated annealing are comparable to those of other optimization techniques developed in this thesis. However, a computational study shows that; in comparison to the simulated annealing technique, significant improvements in optimization control performance and quality of computed solutions can be realized through implementing intelligent techniques. As evidenced by the relative performances of the implemented cooperative schemes, a genetic search is better than a simulated annealing search in the Boltzmann Machine Architecture. In addition, little performance gain can be realized through parallelism in the Boltzmann Machine Architecture. On the other hand, the superior performance of the genetic algorithm that implements an extended diversity control mechanism demonstrates that more competent genetic algorithms can be designed through customized operators.

Therefore, this study has revealed that extending manufacturing optimization concepts through a decoupled optimization method is an effective modeling approach that is capable of handling complex decision scenarios in reconfigurable manufacturing activities. The approach provides a powerful decision framework for process planning optimization activities of a multidimensional nature. Such an approach can be implemented more efficiently through intelligent techniques. Hence; intelligent techniques can be utilized in manufacturing process planning optimization strategies that aim to improve operating levels in reconfigurable manufacturing with the resultant benefits of improved performance levels.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PENGOPTIMUMAN PERANCANGAN PROSES DALAM SISTEM PEMBUATAN YANG DAPAT DIBENTUK KEMBALI**

Oleh

**FARAYI MUSHARAVATI**

**May 2008**

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Cenderung dan perspektif dalam persekitaran dinamik pada masa kini menghala kepada keperluan untuk mengoptimuman tahap proses aktiviti pembuatan yang dapat dibentuk kembali. Tujuan utama untuk memenuhi keperluan ini adalah merupakan teknik yang sesuai untuk pengoptimuman perancangan proses pembuatan, contohnya; (i) apa model pembuatan keputusan yang mana dan (ii) apa computational teknik, memberikan perencanaan proses pembuatan yang optimal pemecahan di tempat variabel keputusan multidimensi? Sambil pengalaman didapati teknik pengoptimuman lazim adalah tidak tepat dan, oleh karena itu, tidak cocok untuk penanganan tepat pencarian multidimensi, perencanaan proses optimization tidak setuju sampai pendekatan memperagakan yang klasik karena tenaga gerak sistem kompleks di pembuatan yang dapat dibentuk kembali. Oleh karena itu, kajian ini meneroka bagaimana untuk memodel semula aktiviti pembuatan yang dapat dibentuk kembali dalam perspektif pengoptimuman dan bagaimana untuk membina dan memilih teknik teknik cerdik untuk proses perencanaan yang dapat dibentuk kembali.

Didalam tesis ini, satu pendekatan baru untuk modeling pengoptimuman perancanagan proses pembuatan (MPPO) telah direka dengan menambaikan konsep pengoptimuman pembuatan lewat memisahkan optimization metode. Keunikan pendekatan ini terdapat pada ematri fungsi menjadwalkan yang diintegrasikan ke dalam perencanaan proses yang diintegrasikan sebahagian fungsi untuk mengeksploitasi potensi strategis fleksibel dan reconfigurability dalam memproduksi sistem. Pelbagai model MPPO telah dibina dan variasi berkaiatan dengan penggunaan dianalisa. Lima (5) pilihan algoritma teknik rekabentuk (AADTs) mengandungi; algoritma Simulated Annealing yang berbeza itu melaksanakan pengetahuan heuristik di ujung keputusan kritis, dua (2) rancangan siasat pencarian koperatif berdasarkan kepada longgar hybridization yang Boltzmann Machine algoritma dengan teknik pencarian algoritma simulated annealing dan genetik dan dua (2) algoritma genetik yang diubahsuai, telah dibangunkan dan diselidik untuk kesesuaian didalam memberikan perencanaan proses pemecahan.

Pertunjukan perbandingan untuk AADTs telah berkembang bila menugaskan untuk memecahkan kejadian masalah MPPO ialah menganalisa dan menilai. Di khusus, pertunjukan relatif variasi baru membuat Simulated Annealing menguatkan, di perbandingan ke: (a) (i) pencarian genetik dan (ii) pencarian simulated annealing, di Boltzmann Machine arsitektur, dan (b) (i) algoritma genetik yang terubah dan (ii) algoritma genetik yang terubah dengan operator yang dibuat menurut pesanan itu melaksanakan perpanjangan inovatif mekanisme kontrol keanekaragaman sampai tingkat gen dan genom; dikejar di tesis ini.

Hasil menunjukkan kelima itu (5) AADTs cakap cakap stabil dan asymptotic persamaan untuk mendekati pemecahan optimal di waktu nyata. Hasil percobaan menunjukkan bahwa pertunjukan variasi yang dilaksanakan membuat Simulated Annealing hampir sama kepada yang dipunyai lain optimization teknik berkembang di tesis ini. Tetapi, computational kajian pameran bahwa; di perbandingan sampai teknik simulated annealing, perbaikan berarti di optimization perbuatan kontrol dan kualitas pemecahan yang diperhitungkan bisa disadari lewat melaksanakan teknik cerdik. Sebagai evidenced oleh pertunjukan relatif rancangan siasat koperatif, pencarian genetik diteukan untuk menjadi lebih baik daripada pencarian simulated annealing di Boltzmann Machine arsitektur. Lagi, dilihat bahwa sedikit perbuatan memperoleh tentang teknik simulated annealing bisa disadari lewat parallelism di Boltzmann Machine arsitektur. Di tangan yang lain, pertunjukan superior algoritme genetik yang melaksanakan mekanisme kontrol keanekaragaman diperpanjang mempertunjukkan bahwa algoritme genetik yang lebih cakap bisa didesain lewat operator yang dibuat menurut pesanan.

Kajian ini sudah mengungkapkan pembuatan memperpanjang itu optimization konsep lewat memisahkan optimization metode adalah pendekatan memperagakan yang efektif yang cakap mengurus aktivitas pembuatan yang dapat dibentuk kembali yang kompleks. Pendekatan seperti itu menyediakan kerangka keputusan sangat kuat untuk pebuatan perencanaan proses aktiviti sifat multidimensi. Oleh karena itu, teknik cerdas bisa digunakan dalam memproduksi perencanaan proses optimization strategi tujuan itu untuk memperbaiki menjalankan tingkat di pembuatan dapat dibentuk kembali dengan keuntungan diakibatkan tingkat pertunjukan yang diperbaiki.

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I certify that an Examination Committee met on the 23 May 2008 to conduct the final examination of Farayi Musharavati on his Doctor of Philosophy thesis entitled "Process Planning Optimization in Reconfigurable Manufacturing Systems" in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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

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## DECLARATION

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

**Farayi Musharavati**

Date: 10 June 2008

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| | |
|---|---|
| **AADT** | Alternative Algorithm Design Technique |
| **AADTs** | Alternative Algorithm Design Techniques |
| **AHP** | Analytical Hierarchical Process |
| **BM** | Boltzmann Machine |
| **BMGAS** | Boltzmann Machine with Simulated Annealing Search |
| **BMSAS** | Boltzmann Machine with Genetic Algorithm Search |
| **CCSs** | Configurable Control Systems |
| **CLPP** | Closed Loop Process Planning |
| **CV** | Coefficient of Variation |
| **DML** | Dedicated Manufacturing Line |
| **DMLs** | Dedicated Manufacturing Lines |
| **DPP** | Distributed Process Planning |
| **FMS** | Flexible Manufacturing System |
| **FMSs** | Flexible Manufacturing Systems |
| **GA** | Genetic Algorithm |
| **GAs** | Genetic Algorithms |
| **GATO** | Genetic Algorithm with a Threshold Operator |
| **GAWTO** | Genetic Algorithm Without a Threshold Operator |
| **GT** | Group Technology |
| **HC** | Handling Costs |
| **HCI** | Handling Costs Index |
| **IAHP** | Interval Analytical Hierarchical Process |
| **MAE** | Modular Actuator Element |
| **MAEs** | Modular Actuator Elements |
| **MCDA** | Multi-Criteria Decision Analysis |
| **MGA** | Modified Genetic Algorithm |
| **MO** | Manufacturing Optimization |
| **MPP** | Manufacturing Process Planning |
| **MPPO** | Manufacturing Process Planning Optimization |
| **MPPs** | Manufacturing Process plans |
| **MRP** | Materials Requirements Planning |
| **MTJs** | Modular Tooling and Jigs |
| **NLMPP** | Non-Linear Manufacturing Process Planning |
| **NLMPPs** | Non-Linear Manufacturing Process Plans |
| **NP, np** | Number of Parts |
| **NPF, npf** | Number of Part Families |
| **OMPI** | Overall Manufacturing Performance Index |
| **OMPIs** | Overall Manufacturing Performance Indices |
| **OPS** | Operating Scenario |
| **OPSs** | Operating Scenarios |

| | |
|---|---|
| **OPT** | Optimized Production Technology |
| **PA** | Part Array |
| **PCA** | Production Cost Array |
| **PCC** | Process Change Costs |
| **PCCI** | Process Change Costs Index |
| **PDS** | Production Scenario |
| **PDSs** | Production Scenarios |
| **PM** | Process Module |
| **PMC** | Process Module Change |
| **PMCI** | Process Module Change Index |
| **PMP** | Processing Machine Primitive |
| **PMPs** | Processing Machine Primitives |
| **PMRVs** | Processing Module Required Vectors |
| **PMSC** | Process Module Similarity Coefficient |
| **PMs** | Processing Modules |
| **PS** | Processing Stage |
| **PSC** | Part Similarity Coefficient |
| **PST** | Processing Types |
| **PVA** | Production Volume Array |
| **QAP** | Quadratic Assignment Problem |
| **RCC** | Reconfiguration Change Costs |
| **RCCI** | Reconfiguration Change Costs Index |
| **RMS** | Reconfigurable Manufacturing System |
| **RMSs** | Reconfigurable Manufacturing Systems |
| **RPP** | Reconfigurable Process Planning |
| **RPPs** | Reconfigurable Process Plans |
| **SA** | Simulated Annealing |
| **SCC** | Set-up Change Costs |
| **SCCI** | Set-up Change Cost Index |
| **SGA** | Simple Genetic Algorithm |
| **SM** | Synchronous Manufacturing |
| **TAD** | Tool Approach Distance |
| **TC** | Tool Costs |
| **TCC** | Tool Change Costs |
| **TCCI** | Tool Change Cost Index |
| **TCI** | Tool Cost Index |
| **TSP** | Traveling Salesman problem |
| **VCMS** | Virtual Cellular Manufacturing Systems |
| **VISM** | Visual Interactive Simulation Modeling |
| **WS** | Work Station |
| **XS** | Change in Production Scenario |
| **XSs** | Change in Production Scenarios |