PROCESS PLANNING OPTIMIZATION IN RECONFIGURABLE MANUFACTURING SYSTEMS

Process Planning Optimization in Reconfigurable Manufacturing Systems

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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

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.

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LIST OF ABBREVIATIONS

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

CHAPTER 1

INTRODUCTION

Dynamic and competitive environments require that manufacturers meet various production requirements without compromising operating efficiencies. Such demands are stretching the limits of conventional manufacturing systems thereby presenting challenges for manufacturers. To face up to these challenges, reconfigurable manufacturing systems (RMSs) have been introduced in the manufacturing arena.

The ultimate vision of a reconfigurable manufacturing system (RMS) is to "provide the exact capacity and exact functionality exactly when it is needed" (Koren and Ulsoy, 2002). There is little room for incompetence when making decisions for such systems. Best models for handling decision scenarios must be utilized. Likewise, appropriate techniques that provide optimal manufacturing solutions must be implemented. This thesis focuses on a study of manufacturing optimization as one facet that can be used to develop effective decision making tools that help manufacturing engineers to make the best production decisions. Implementation of such optimization tools in reconfigurable manufacturing can enable realization of the broader goal of current research in RMSs: i.e. developing truly reconfigurable manufacturing systems.

1.1 Background

The global market is dynamic and extremely competitive. Manufacturers are competing to satisfy varying production requirements at the most efficient levels. The challenge is to implement processes that are customer responsive and produce products that satisfy customers. However, the demands of dynamic environments are stretching the limits of conventional manufacturing systems operating in environments where changes to production requirements are random (Mehrabi et al., 2002). To alleviate this strain on conventional manufacturing, academic research has introduced new and innovative ways of designing manufacturing systems that can face up to the challenges of change dynamics in the manufacturing landscape (Koren and Ulsoy, 2002; Koren et al., 1999). Such efforts have culminated in the advent of reconfigurable manufacturing systems (RMSs).

Nevertheless, implementation of an appropriate or well-designed manufacturing system alone is not a panacea for success (Harrison and Petty, 2002; Higgins et al., 1996). This is because the manufacturing system is only part of the total production system and requires, among other things, an equally competitive and appropriate manufacturing support system.

Despite the fact that both a well-designed manufacturing system and an appropriate manufacturing support system can allow manufacturers to effectively address challenges in dynamic environments, there has been little research done on developing manufacturing support systems that are in tandem with technological advancements which culminated in RMS concepts and techniques. This is evident from a forum of discussions by experts in reconfigurable manufacturing technologies, as discussed in (ElMaraghy, 2006), in which development of logical support systems for RMSs has been identified as one of the challenges to reckon with in advancing the state of art in reconfigurable manufacturing.

Lack of appropriate manufacturing support systems for reconfigurable manufacturing is a situation that is in striking contrast to that in conventional manufacturing systems. A variety of manufacturing support systems have been developed and upgraded to match subsequent changes and variations in design and operational characteristics in conventional manufacturing (Higgins et al., 1996). However, such a variety is not available to assist manufacturing engineers in making production decisions for reconfigurable manufacturing.