Chapter 10
Constrained Optimization of JIT Manufacturing Systems with Hybrid Genetic Algorithm

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ABSTRACT

This research explores the use of a hybrid genetic algorithm in a constrained optimization problem with stochastic objective function. The underlying problem is the optimization of a class of JIT manufacturing systems. The approach investigated here is to interface a simulation model of the system with a hybrid optimization technique which combines a genetic algorithm with a local search procedure. As a constraint handling technique we use penalty functions, namely a "death penalty" function and an exponential penalty function. The performance of the proposed optimization scheme is illustrated via a simulation scenario involving a stochastic demand process satisfied by a five–stage production/inventory system with unreliable workstations and stochastic service times. The chapter concludes with a discussion on the sensitivity of the objective function in respect of the arrival rate, the service rates and the decision variable vector.

INTRODUCTION

This chapter addresses the problem of production coordination in serial manufacturing lines which consist of a number of unreliable machines linked with intermediate buffers. Production coordination in systems of this type is essentially the control of the material flow that takes place within the system in order to resolve the trade-off between minimizing the holding costs and maintaining a high service rate. A time-honored approach to modeling serial manufacturing lines is to treat them as Markov Processes (Gershwin, 1994, Veatch and Wein, 1992) and then solve the related MarkovDecisionProblem, (MDP), by using standard iterative algorithms such as policy iteration, (Howard, 1960), value iteration, (Bellman, 1957) etc. However the classic dynamic programming, (DP), approach entails two major drawbacks: Bellman's curse of dimensionality, i.e. the com-

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putational explosion that takes place with the increase of the system state space, and the need for a complete mathematical model of the underlying problem. The limitations of the DP approach gave rise to the development of sub-optimal yet efficient production control mechanisms.

A class of production control mechanisms that implement the JIT (JustInTime) manufacturing philosophy known as *pull type* control policies/mechanisms has come to be widely recognized as capable of achieving quite satisfactory results in serial manufacturing line management. Pull type control policies coordinate the production activities in a serial line based only on actual occurrences of demand rather than demand forecasts and production plans as is the case in MRP-based systems. In this chapter, six important pull control policies are examined, namely Kanban and Base Stock (Buzacott and Shanthikumar, 1993), Generalised Kanban (see Buzacott and Shanthikumar (1992), for example), Extended Kanban (Dallery and Liberopoulos, 2000), CONWIP (Spearman *et al*., 1990) and CONWIP/Kanban Hybrid (Paternina-Arboleda and Das, 2001). Pull production control policies are heuristics characterised by a small number of control parameters that assume integer values. Parameter selection significantly affects the performance of a system operating under a certain pull control policy and is therefore a fundamental issue in the design of a pull-type manufacturing system. In this chapter the performance of JIT manufacturing systems is evaluated by means of discrete-event simulation (Law and Kelton, 1991). In order to optimize the control parameters of the system the simulation model is interfaced with a hybrid optimization technique which combines a genetic algorithm with a local search procedure.

The application of simulation together with optimization meta-heuristics for the modeling and design of manufacturing systems is an approach that has attracted considerable attention over the past years. In Dengiz and Alabas (2000) simulation is used in conjunction with tabu search in order to determine the optimum parameters of a manufacturing system while Bowden *et al*. (1996) utilize evolutionary programming techniques for the same task. Alabas *et al.* (2002) develop the simulation model of a Kanban system and explore the use of genetic algorithm, simulated annealing and tabu search to determine the number of kanbans. Simulated annealing for optimizing the simulation model of a manufacturing system controlled with kanbans is applied in Shahabudeen *et al.* (2002), whereas Hurrion (1997) constructs a neural network meta-model of a Kanban system using data provided by simulation. Koulouriotis *et al.* (2008) apply Reinforcement Learning methods to derive near-optimal production control policies in a serial manufacturing system and compare the proposed approach to existing pull type policies. Some indicative applications of genetic algorithms (GAs) in manufacturing problems can be found in Yang *et al.* (2007), Yamamoto *et al* (2008), Smith and Smith (2002), Shahabudeen and Krishnaiah (1999) and Koulouriotis *et al.* (2010). Panayiotou and Cassandrass (1999) develop a simulation-based algorithm for optimizing the number of kanbans and carry out a sensitivity investigation by using finite perturbation analysis. It has been suggested in the literature that the results of a genetic algorithm can be enhanced by conducting a local search around the best solutions found by the GA, (for related work see Yuan, He and Leng, 2008 and Vivo-Truyols, Torres-Lapasio and Garcıa-Alvarez-Coque, 2001). On that basis, this hybrid optimization scheme has been adopted in the present study.

The main contributions of this work are the following. The performance of six important pull production control policies in a hypothetical scenario is investigated using discrete event simulation. In order to determine the control parameters of each policy the proposed hybrid GA is employed. The objective function to be optimized is a weighted sum of the mean WorkInProcess, (WIP), inventories subject to the constraint of maintaining the service level, (*SL*), above a specified target. Due to

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