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Simulative Assessment of Agent based Production Planning and Control Strategies

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Abstract

To capture the dynamics in flexible manufacturing systems and derive appropriate production planning and control (PPC) strategies, simulation has proven to be a promising method. However, many simulation approaches focus on supply chain aspects, discrete production steps or were modeled for specific use cases involving a high degree of complexity. This paper presents an approach to structure manufacturing systems including parametrizable jobs, products and machines. It provides the option to choose from a normal, an energy- or time-efficient PPC strategy either minimizing the required time or energy demand. As a result, improved case-specific PPC strategies can be derived.

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Keywords: Production planing and control strategies; Simulation; Time Effficiency; Energy Efficiency; Agents

1. Introduction

Nowadays, manufacturing companies face various challenges such as growing global competition and therefore increasing cost pressure, rapid technological progress, decreasing resources, increasing environmental challenges or the need for individualized products. These trends entail shorter product life cycles while producing a higher number of product variants as a result from more fluctuating customer demands. As a result, manufacturing paradigms have changed over the last two centuries leading to altered or new manufacturing systems (MS) and operations to account for the external, market driven requirements at the respective time [1]. At the beginning there was traditional craft production of individual products in small job shops. Sequential assembly lines have then been introduced as a next stage of evolution for efficiently producing high volumes of identical products, following the ideas of Taylorism. In the second half of the 20th century, the lean manufacturing paradigm brought to light new elements and principles such as continuous production or one-piece-flow which were for instance realized by implementing flexible production cells. The invention of NC machines then facilitated the creation of new so called Flexible Manufacturing Systems (FMS) in the early 1980s [2], allowing for mass customization of products.

Today's trend towards personalized products demands for even more flexible MS, accelerating the need for further adaptations. Hence, satisfying the customer demands while producing cost-efficient in lot size 1 will be even more challenging for manufacturing companies. This situation is further exacerbated when stochastic system failures are included in the considerations despite having the need for maintaining an ongoing production to remain profitable [2]. As a consequence, modern MSs must feature an increased responsiveness to changes e.g. through flexible structures or flexible Production Planning and Control (PPC) strategies.

2. Background

2.1. Characteristics of flexible manufacturing systems

Manifold definitions for flexibility in the context of production have emerged in research, as it has become a topic of high relevance during the last decades. In a general manner, flexibility can be described as the capacity of a system to change and assume different positions or states,

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responding to changing requirements with low efforts like costs, time consumption or performance losses [3]. A popular classification comprises ten categories, allowing to characterize the flexibility of a MS [4,5].

Table 1. Flexibility categories for MS [4,5]

Flexibility Type	Explanation
Machine	Ability of machines to perform different operations without set-up change
Material Handling	Number of possible paths between all machines
Operation	Number of different processing plans available for part processing
Process	Set of part types that can be produced without major set-up changes
Product	Introducing products into an existing product mix
Routing	Number of feasible routes of parts
Volume	Ability to vary production volume
Expansion	Capability to physically expand the system
Control Program	The ability of a system to run virtually uninterrupted due to intelligent machines and system control software
Production	Number of all part types that can be produced without adding major capital equipment

Research has also identified different types of MS, depending on their degree of flexibility and their suitability for different market demands. An easy distinction can be made between three general types - Dedicated Manufacturing Systems (DMS), Reconfigurable Manufacturing Systems (RMS) and Flexible Manufacturing Systems (FMS) [6-8]. DMS consist of highly specialized machines with a very high rate of production for the single part type they produce. Hence, DMS were the enabler for mass production, starting with Henry Ford's moving assembly line, which allowed for a profitable way to produce high volumes [1,8]. FMS are systems which machines can produce different types of parts with little or no time or other effort for changeover. Usually these machines are processing stations and handling systems under computer control (CNC) for the automatic processing of pre-defined part families [8]. RMS is designed for rapid change in structure in order to quickly adjust capacity and functionality, which is enabled by two main aspects: First, the machines become Reconfigurable Machine Tools (RMT) through standardized and easy to change components. Second, self-adapting software systems allow for the quick and seamless integration of modular hardware [8,9]. However, these types of MS are not able to dynamically adapt to disturbances and a highly dynamic environment, but have to be stopped for adaptations [10,11]. Therefore, other MS types are needed that can be designated as Agile Manufacturing Systems (AMS) [12]. One kind of AMS is the Holonic Manufacturing System (HMS), describing a Multi-Agent System (MAS), which elements like products, machines and jobs act as autonomous cooperative agents, making decentralized decisions [13,14]. Such a system is intended to be resistant to disturbances and allows for an efficient use of resources, if suitable decentralized control strategies are applied [10,15,16].

2.2. PPC strategies

Optimal production planning and scheduling is a major challenge for manufacturing companies. Particularly the task of job shop scheduling (JSS), allocating production jobs and resources like machinery, human and material is very complex. However, the basic problem can be described very simple as a number n of different jobs that need to be scheduled on m machines with the goal to minimize the lead time. In practice, the planning problem usually is much more complex due to multiple job and machine constraints, more complex MS structures and various target criteria. Hence, mathematical algorithms and simulation techniques are usually employed to generate optimal or at least good production schedules. Although the challenge of PPC has been studied for several decades, there is still a lot of ongoing research in this field. For an up to date overview see the review study of Negahban & Smith, comprising 290 recent papers [17]. A general overview about PPS approaches developed to solve the problem of JSS, dividing the existing approaches into two groups of techniques, is provided by Arisha et al. (see Fig. 1) [18].

In practice, the techniques related with priority rules – also referred to as dispatching rules – have the highest relevance, as they are easy to implement, aiming at good but not necessarily optimal solutions in a relatively short time [19]. Over the last decades, numerous rules have been described and examined regarding their performance in different PPC situations [20-23]. In the simplest form, priority rules order the jobs waiting in front of a machine according to some local criterion, assigning the highest priority job to the machine as soon as it is available [22]. Typical rules of this kind are for instance FIFO (first in first out), LIFO (last in first out), EDD (earliest due date), SPT (shortest processing time) or SRPT (shortest remaining processing time) [23]. However, none of the available rules generally outperforms the others for practical problem settings [18], hence the choice for a suitable priority rule has to be made considering the current situation and targets.

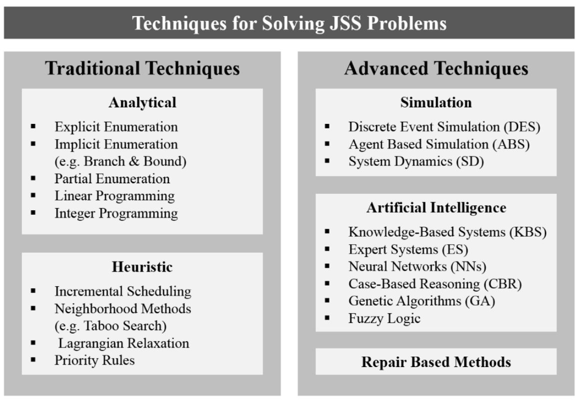

Fig. 1. Techniques for solving JSS problems, adapted from [18].