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Multi-agent systems in production planning and control: An application to the scheduling of mixed-model assembly lines☆

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Abstract

This work deals with *production smoothing*, one of the keys of success of *Just In Time* and *Lean Production*. By levelling the load of the workstations, production smoothing allows a regular material flow, shorter manufacturing lead times, and lower work in process. Different solutions to the mixed-model assembly lines sequencing problem have been proposed in literature. In this paper, a Multi-Agent System is presented, which solves this problem according to the theory of autonomous agents. The experimental results show that this innovative approach has a good performance if compared with the traditional ones.

Keywords: Production smoothing; Multi-agent system

1. Introduction

Short-term production planning techniques have known a long evolution starting from the Seventies. After a first era of optimisation dominion, heuristic approach tried to overcome its limitations, yet introducing others. Later, researchers' attention shifted to other innovative paradigms, which are more effective in modern dynamic and complex contexts. In particular, one of these approaches is Artificial Intelligence (AI): nowadays *autonomous agent theory*, a product of AI, is one of the most interesting fields of research as far as production planning and control are concerned. The topic of this paper is an application of autonomous agent theory to a particular short-term production planning problem, sequencing of mixed-model lines, which has been studied for years in literature.

After a brief overview of the evolution of short-term production planning techniques across last decades (Section 2), an introduction to autonomous agent theory and multi-agent architectures is reported in Section 3. Later, in Section 4, the problem of sequencing of mixed-model assembly lines is presented, together with the model usually adopted in literature in order to solve this problem. Once modelled, the problem can be solved through different techniques: in particular, the section presents the heuristic and the optimisation approaches, as they have been developed in literature; moreover,

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Table 1
Synoptic table of scheduling techniques

Era	Control	Approach	Technique
Optimisation	Hierarchical	Automatic	Optimisation or heuristic
Heuristic	Hierarchical	Automatic	Heuristic
Complexity			
Artificial intelligence	Hierarchical	Automatic	Heuristic
Neural networks	Hierarchical	Automatic	Heuristic
Genetic algorithms	Hierarchical	Automatic	Heuristic
Autonomous agents	Distributed	Automatic	Heuristic
Interactive schedulers	Distributed (control is delegated to the operator)	Interactive	Heuristic + operator

it proposes a multi-agent architecture which has been recently developed by the authors. The performance of this architecture has been tested and compared with other performing models: the experimental results, shown in Section 5, suggest the existence of significant margins of improvement on the performance of traditional approaches.

2. The evolution of short-term production planning techniques

Four principal moments (*eras*) of evolution can be identified for short-term production planning techniques:

- optimisation era,
- heuristic era,
- complexity era,
- interactive schedulers era.

The synoptic table of the four above-mentioned techniques is reported in Table 1 and a brief description of each of these is provided subsequently (see also [1]).

2.1. Optimisation era

Seventies and Eighties are the ages of Computer Integrated Manufacturing (CIM). Its characteristic is a strongly hierarchical top-down control and full automation of manufacturing system. The application of this technique has not encountered great success in real world applications mainly because of the following reasons:

- reaching full automation in a manufacturing system takes a long time while, on the other hand, market needs quick response (shorter and shorter time-to-order and time-to-market are required);
- standardisation, which is a natural consequence of automation, makes the firm too strict to face the requirement of product differentiation;
- representing complex real manufacturing systems through computerised algorithms is very hard because it implies the translation of system processes and decisional rules into an analytical model (which contains equations and linear/not-linear relationships among the variables of the system);
- a deep dichotomy exists between algorithmic mono-objective approach and actual multi-objective context.

As soon as these limitations were understood, integrated optimisation started to be considered an utopian paradigm while an opposite approach, the heuristic one, took place.

2.2. Heuristic era

Heuristic paradigm dominated the Eighties. It originated from the need for overcoming the difficulties of a deep modelling of reality, offering a more efficient (quicker) decision support instrument; in fact, generally speaking, an heuristic algorithm is usually nothing but the flow chart of the mental steps followed by the planner in making decisions. Compared with the optimisation