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Towards robust and efficient planning execution

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Abstract

This paper presents a holonic manufacturing execution system (MES) that cooperates with a planning system. This cooperation allows to combine the robustness and flexibility of the holonic MES with the optimisation performed by the planning system.

The paper investigates the effect on the global performance of this cooperation for a specific manufacturing case in a series of experiments. It compares the effect of this cooperation when the planning is optimal with regard to the manufacturing case with situations where the planning system is not optimal. More precisely, it compares the performance of the HEMS in situations where the planning systems systematically misestimates the execution time of a workstation (e.g. a poorly maintained workstation or a partially operational workstation) to situations where this is not the case.

The experiments are conducted under varying work loads. Also, the effort the Holonic MES puts in finding new solutions resembling the planning is varied.

Finally, the paper reports the results of the experiments and draws conclusions.

Keywords: Holon; HMS; Ant colony engineering; Multi-agent; Planning system

1. Introduction

Operations management on factory floors generally involves planning and execution. Planning activities generate directions for the production activities, typically on beforehand, aiming to optimise the organisations objectives (e.g. low cost, high yield).

The manufacturing execution system or MES aims at the actual achievement of the production objectives while accounting for all the relevant details and unforeseen events; thoroughness and robustness come before optimality.

Obviously, manufacturing organisations want optimality together with robustness and thoroughness. Therefore, this paper presents an extension and enhancement of a holonic manufacturing control system—implemented as a situated multi-agent system—that cooperates with planning systems. The agents in the control system follow a planning if and when it performs well. Otherwise, the agents use autonomous decision-making mechanisms to find and execute alternatives that resemble the original planning well. In a future step, the situated multi-agent system can feed the planning system with a short-term forecast of the state of the manufacturing system, thus establishing a true cooperation. This aspect is not treated in this paper.

2. Holonic MES

This section concisely describes the baseline holonic manufacturing execution system or HMES. It contains background information to keep this paper readable by itself. More detailed information can be found in Valckenaers and Van Brussel (2005), Van Brussel et al. (1998), and Wyns (1999).

The HEMS is implemented by a multi-agent system along the PROSA architecture (Van Brussel et al., 1998; Wyns, 1999). It comprises three basic agent types. First, there are the resource agents that manage all the resources on the factory floor. Second, every product type has a product agent that knows how instances of this product type can be produced by the factory resources. Third, every production task is handled by its order agent. An order agent consults the product agent to find out what

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operations it should perform on its (partially instantiated) product. Next, it searches for the proper resources to perform the required operations.

Furthermore, the HEMS uses ant colony inspired coordination mechanisms (Valckenaers and Van Brussel, 2005). Every order agent creates lightweight agents, called exploring ants, that scout for possible solutions on its behalf. The order agents select a best solution out of the solutions reported back by their exploring ants, which is nominated to become their intention. A second type of lightweight agents, called intention ants, reserves the necessary capacity on the resources that are indicated in this intention. Note that both kinds of ant agent are created regularly to refresh existing information or discover new information. Information that is not refreshed disappears after some time (evaporates).

3. Cooperation of planning systems and the holonic MES

This section discusses the research contribution. First, it discusses the current situation and the objectives of the research. Next, it presents a series of experiments which investigate the effect of the cooperation on the performance of the holonic MES, not considering disturbances. The experiments apply to a specific factory under varying work loads, with varying fitness of the planning to the current situation on the shop floor. Also, the effort the Holonic MES puts in finding new solutions resembling the planning is varied.

3.1. Current situation

Production in a factory is generally organized according to a planning (Daniel Sipper, 1997). This planning is created before execution starts. From the MES perspective, such planning never provides all the relevant details. Typically, it does specify which jobs need to be performed on which machines, in what time period. It does not specify details like which transportation unit to use for carrying parts from and to machines, where to store parts, which tools to use to manufacture parts, etc. The planning is released on a regular base (e.g. weekly, daily, every shift or hour).

Generally, production activities deviate from this planning within the proverbial first minutes. The production floor continues to use release dates and due dates in the planning but otherwise manages the activities on the shop floor autonomously.

Further developments in planning technology will not solve this problem. Up-front planning cannot handle unpredictable outcomes or unforeseen events (quality control results, machine breakdowns). Also, the computational complexity for the real planning problem is NP or worse. Planning systems efficiently solve a simple problem (e.g. a linear program) that represents a much simplified and approximated view of the real-world problem. Accounting for all the relevant details makes the planning problem intractable. Executing the planning procedures repeatedly on-line also fails to address all issues. Typically, the planning is outdated and invalidated by the time it is released; the more detailed the planning is, the worse this problem will be. Furthermore, drastic changes between successive plans often make the planning unusable in practice as well as unpopular with the workforce.

3.2. Research objectives

The above observations reveal that manufacturing organisations have two objectives concerning the shop floor operations:

- Optimisation of production performance relative to the management goals (reduce costs, satisfy customer demand). Today planning systems have been conceived and constructed to address this concern.
- Robustness and thoroughness, or the realisation of the production objectives, derived from management goals, while accounting for all the relevant details and handling uncertainties and unforeseeable disturbances. Manufacturing execution systems and especially holonic MES have been developed to address this concern.

Therefore, the research investigates and elaborates a cooperation between a holonic MES and planning systems such that good performance is reconciled with robust execution. This cooperation avoids that either subsystem imposes stringent constraints on the other or that either system requires intimate knowledge about the other.

3.3. Related work

Dynamic scheduling (Cowling and Johansson, 2002) is a broad research field that attempts to compensate the shortcomings of traditional planning approaches in dynamic manufacturing environments by making use of rescheduling and schedule repair techniques. Current research focusses on specific techniques and measures to perform these activities.

The research in this paper uses a richer and more accurate model of the shop floor reality than current research. This model is designed to represent the shop floor reality, it is not chosen in function of a particular optimisation strategy. This local status information, together with the capability to make short term forecasts (Valckenaers and Van Brussel, 2005), allows the HEMS to discover possible problems in the planning and to adapt them.

The research is complementary to the research in the dynamic scheduling area; it is not limited to one particular rescheduling strategy. Many rescheduling/repair techniques can readily be used in the HEMS. An overview and comparison of the use of these different techniques in the HEMS is subject of further research.