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Engineering Applications of Artificial Intelligence 16 (2003) 307–320

Engineering Applications of
ARTIFICIAL INTELLIGENCE

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Benchmarking and robust multi-agent-based production planning and control

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Abstract

Multi-agent systems (MAS) offer new perspectives compared to conventional, centrally organised architectures in the scope of production planning and control. They are expected to be more flexible and robust while dealing with a turbulent production environment and disturbances. In this paper, an MAS is developed and compared to an Operations Research Job-Shop algorithm using a simulation-based benchmarking scenario. Environmental constraints for a successful application of MAS are identified and classified. Furthermore, the topic of MAS robustness is addressed by applying database technologies on the basis of transactions.

Keywords: Modelling; Simulation; Production planning; Scheduling; Flexibility; Reliability and multi-agent approach

1. Introduction

Companies nowadays have to face a global market characterised by numerous competitors, a steadily increasing complexity of business processes and a highly turbulent production environment. Consequently, manufacturing systems have to provide the flexibility and reliability that is required to stay competitive.

Decentralised planning and controlling approaches offer interesting perspectives compared to conventional centralised architectures. In the scope of production planning and control (PPC), multi-agent systems (MAS) are expected to be more flexible than centrally organised systems. Nevertheless, they lack of reliability and robustness that is necessary for an industrial deployment.

To prove or disprove the thesis of MAS being more flexible and thus being able to increase the planning quality for well-defined shop floor scenarios, a simulation-based benchmarking platform on the basis of a real test case scenario was developed at the University of Karlsruhe in the scope of the Karlsruhe Robust Agent SHell (KRASH) project. A performance measurement system is included to provide not only qualitative, but also quantitative results. The platform is used to compare existing PPC approaches based on Operations Research (OR) algorithms with decentralised MAS approaches. Furthermore, different scenarios can be simulated with various levels of complexity. This makes it possible to set up a map that identifies application scenarios, where MAS provide a real benefit to potential industrial users. In the next step, abstract rules can be extracted from these results to gather further knowledge about the preferences of MAS.

Besides the quality of the planning results, robustness is a very important aspect of a manufacturing system, especially since the focus of the project is set upon handling disturbances like machine troubles or tardiness caused by external suppliers. On the shop floor, reliability may be guaranteed by sophisticated planning algorithms.

On the other hand, the software implementation of the MAS has to be robust, too. Due to the distributed architecture consisting of autonomous and intelligent entities, MAS are more error-prone compared to central approaches. Thus, special attention has to be paid to technical robustness issues. Robustness and reliability are common features of modern database systems. Consequently, database technologies are used to provide services that guarantee the robust execution of agent tasks. The implementation of robust MAS is simplified by defining a framework for the transaction-based

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0952-1976/$ - see front matter
doi:10.1016/S0952-1976(03)00075-7

execution of agent tasks. Local and dispersed agent plans are executed in a robust way by using a transaction service. Its performance and scalability was evaluated by using simulation technologies.

In Section 3, the simulation-based benchmarking platform is described. The developed MAS approach is presented in Section 4. Section 5 shows the results of the comparison of the centralised and decentralised planning approaches and draws conclusions of the results. The transaction-based robustness service and simulation results are introduced in Section 6. Section 7 summarises this paper.

2. Benchmarking scenario

In this project, the suitability of MAS in the range of production planning and control is analysed. The transferability of the results upon industrial shop floor scenarios is one of the major prerequisites of the KRASH project. Thus, the evaluation has to be performed on the basis of a real, or at least a realistic, production scenario. Besides the industrial relevance, the application of MAS has to be motivated. In technical literature (for example Weigelt and Mertens, 1999; Spieck et al., 1995 or Cavalieri, 2000), MAS are described to be more flexible and robust in a dynamic, turbulent production environment compared to centralised approaches. In addition, they are able to handle complex production planning problems more effectively by dividing them into less complex partial planning problems. As a consequence, the scenario has to be characterised by

- a sufficient production planning complexity,
- the occurrence of short-term disturbances like machine failures, and
- features like robustness and flexibility have to be key requirements.

The benchmarking scenario is based upon a circuit breaker production plant. The shop floor layout is depicted in Fig. 1. Within this plant, a production area ("Unit Assembly Area") is chosen, where components are assembled that are used in the final assembly later. The area consists of 13 assembly lines. Six different component families and four sub-component families, that are part of the components, are assembled. Thus, the test case represents a multi-level assembly.

The material flow is controlled by a Kanban system (Ohno, 1993). As it is mentioned above, the component assembly is the predecessor of the final assembly. The raw material consumption in the final assembly determines the production in the component assembly. The orders in this area, including start dates, product IDs and quantities have been extracted in a simulation study beforehand, so this part of the plant can be analysed separately to reduce to complexity of the task in a reasonable way. The correctness of the order data has been approved by the industrial partner that runs the production plant.

A Kanban system is especially suitable for the integration of a MAS. Both systems are highly distributed, since Kanban consists of decentralised, self-controlling control cycles. In this project, one of the control cycles is internally planned and controlled by a MAS. To level the workload of the machines, a line balancing has to be performed. The main goal while setting up a Kanban system is the minimisation of the internal buffer stock. The two parameters that directly affect the buffer stock are the maximum consumption rate of the raw material and the maximum replenishment lead time (Ohno, 1993). The problem of

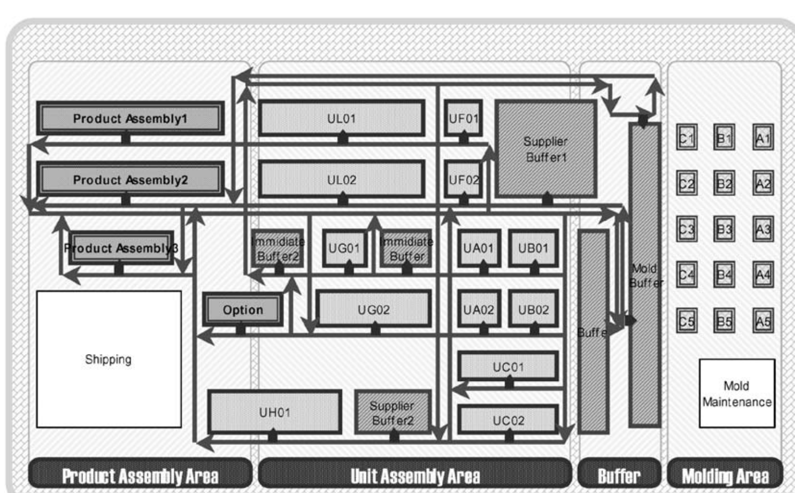

Fig. 1. Shop floor layout.