MAS for manufacturing control: A layered case study (Extended Abstract)

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ABSTRACT

The usage of multi-agent systems for manufacturing control seems to be sharply contrasted by classical mathematical control theory. This work emphasizes how views from both scientific fields can be combined to create the flexible and optimal manufacturing control systems of tomorrow.

Categories and Subject Descriptors

J.7 [**Computer-aided Engineering**]: Computer-aided manufacturing

General Terms

Performance, Design, Theory, Algorithms, Experimentation

Keywords

Multi-agent systems, manufacturing control, optimization, layered control system.

1. INTRODUCTION

The manufacturing industry in the western world is undergoing a paradigm shift from mass production to more specialized, customized production. In addition, the industry is experiencing increasingly diverse and volatile demands from the market [3]. The traditional control systems in the manufacturing industry are typically centralized and monolithic in structure [2]. Multi-agent manufacturing control is proposed as a new way of dealing with these challenges. Such control systems is said to have characteristics such as flexibility, agility and modularization which current rigid hierarchical control systems does not have. Some examples of such architectures can be found in [1].

In the field of control theory the notion of an agent is not very frequently used. However, multi-agent systems (MAS) is an architecture which is decentralized in nature, and as such it puts restrictions on the possible control algorithms which can be implemented. It is well known that the interconnection of locally optimal objectives does not necessarily give a globally optimal objective. As an example, if the agents are greedy non-cooperative game theory states that the total system will converge to a Nash equilibrium which need not be the same as the globally best solution [4]. Rawlings and Stuart [6] show that a network of optimal controllers can be suboptimal and in fact also unstable if not special care is taken.

If measuring the performance of a control system with some objective function J (to be maximized), at an instant T a centralized control structure, J_c, may be more optimal than a decentralized one, J_{dc}, such that $J_c(T) \geq J_{dc}(T)$. If the centralized structure implements some globally optimal solution, the difference $J_c(T) - J_{dc}(T)$ is said to be a *optimality gap* [5].

When considering a production plant, it may have thousands of measurements and control loops. The issue of plantwide control considers control system design with emphasis on the structure of the overall plant [7]. It is in the realm of plantwide control that the justification for the usage of MAS is found. MAS are architectures that implicates a decentralized control approach for plantwide control that aims to provide the system with a degree of robustness to variances. These variances can often be divided into operational variances, like rate of throughput, or external variances, like marked conditions. That is, the system should be able to function under the full range of operating conditions, internal and external, with- out the need for reconfiguration. The multi-agent community thus often empathizes that *decentralized decision making can make a control system more flexible when compared to a fully integrated (centralized) implementation.*

Although there may be a centralized control structure available that is specialized for the operating conditions *today*, it may be more beneficial to implement a decentralized structure that can also cope with the uncertainty of *tomorrow* with minimal need for expensive and time consuming reconfigurations. That is, over time the integral of the objective function may be larger for the decentralized control structure because it can handle larger variety of operating conditions, such that $J_{dc}(t)dt \geq J_c(t)dt$. The idea is illustrated in Figure 1.

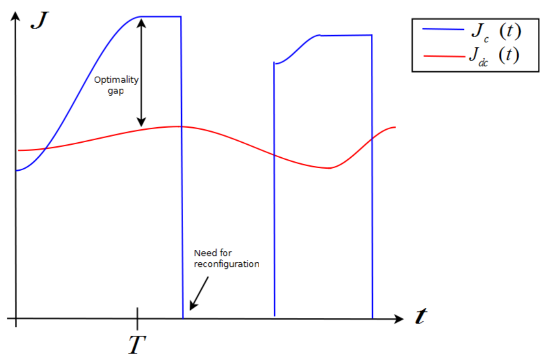

Figure 1. Optimality over time.

The multi-agent publications mentioned in the first paragraph all give excellent qualitative arguments for the use of MAS in manufacturing that follows in the lines of these arguments. More mathematical control oriented literature, on the other hand, often emphasize the optimality gap and thus argues the usage of centralized control structures. A simple idea is that *both* the optimality gap *and* the difference in accumulated difference in objective functions should be weighted, thus giving a good balance between **optimality now** and **flexibility later**. It seems to be of vital importance to explore how one can achieve such a balance. As most traditional control systems are hierarchical, examining a layered approach to multi-agent control can provide a more smooth transition into new multi-agent control systems.

2. CONTROL SYSTEM LAYERING

We consider a manufacturing plant where two control problems are to make production and distribution schedules at minimal cost. Two non-layered setups are proposed in addition to a layered setup for control of this plant.

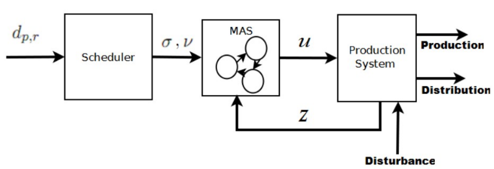

Figure 2. Multi-agent control with scheduling.

- **Single node:** The production and distribution schedule are applied directly to the simulator. The production system tries to follow this schedule strictly even in the event of disturbances.
- **Multi-agent control without scheduling:** A MAS produces and delivers orders without any scheduling layer. The orders are produced and delivered in a first-come-first-served fashion.
- **Multi-agent control with scheduling:** The schedule is fed into the MAS, as shown in Figure 2. Under normal operating conditions, the MAS follows the schedule strictly. However, in the event of disturbances, typically local interactions of agents algorithms will cause the system to deviate from the schedule.

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4–8 June 2012, Valencia, Spain.

Simulations are being done on a computer software impleme nted as shown in Figure 3. Preliminary results show that a proposed MAS can cope with variances in a more flexible way than pure centralized control. Layering the MAS with a central node also improves coordination and reduces the optimality gap.

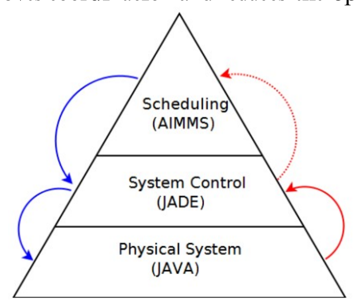

Figure 3. A layered control approach.

3. CONCLUSIONS

Many manufacturing control systems are hierarchical, and developing layered multi-agent control systems would provide the opportunity for a more smooth transition in implementation that can utilize the systems already in place. More work should also be done investigating possible performance benefits with such layered approaches, as simulation results show it can in fact improve system performance when compared to pure multi-agent control.

4. ACKNOWLEDGMENTS

This work is in part funded by FP7 NMP Grace project Contract n° NMPP2-SL-2010-246203.

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