Agent-based Control of Manufacturing Systems

PROJECT OBJECTIVE

Develop the various agents needed for multi-agent control of manufacturing systems, improve the coordination of these agents, and analyze the performance of the multi-agent control strategy

BENEFITS

- ✓ Improves the adaptability and flexibility of manufacturing systems to machine failures and disturbances in the system
- ✓ Allows for a variety of parts to be produced by a manufacturing plant
- ✓ Enables more modular manufacturing systems
- ✓ Simplifies and shortens the necessary time to configure a large manufacturing system

MOTIVATION AND CHALLENGE

To stay competitive in the global market, manufacturing companies must quickly and efficiently respond to rapid changes in product demand, varying customer requirements, and malfunctioning equipment. Traditional control strategies are able to guarantee certain performance characteristics when the plant is working as predicted, but they lack the reconfiguration ability to adapt to unforeseen issues. Thus, manufacturers need to leverage other types of advanced control technologies to address some of these issues on the plant floor. One type of strategy that can be utilized is multi-agent system control of manufacturing systems.

Even though multi-agent systems have previously been studied in the research community, the following challenges remain:

1. Identifying rigorously defined communication, internal structures, and control methods for the various types of agents
2. Incorporating predictive learning methods in agents to enable more intelligent decision making capabilities
3. Creating a standardized framework that can be generalized to real-world manufacturing systems
4. Analyzing and validating multi-agent architectures that have been proposed for manufacturing system control

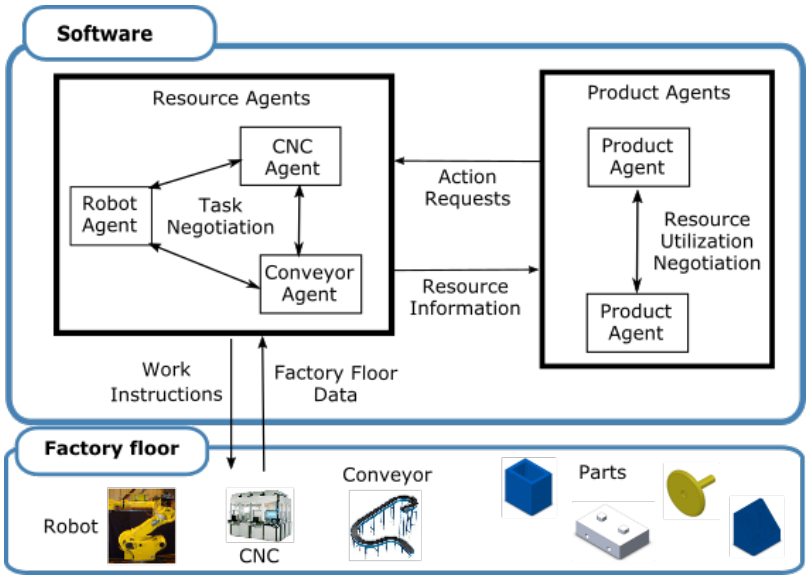
OVERVIEW OF THE WORK

The multi-agent control strategy can improve the performance of manufacturing systems in uncertain or dynamic environments. The goal of this work is to rigorously define, analyze, and improve the performance of a manufacturing system that is run by a multi-agent controller. The proposed work will provide the following contributions:

- Well-defined architectures for various types of agents in a manufacturing system
- Development, implementation, and evaluation of multi-agent algorithms to improve manufacturing system performance
- A generalizable framework that can be used for control of a variety of manufacturing systems
- An evaluation of the performance of a multi-agent controlled manufacturing system

PROJECT DESCRIPTION

The multi-agent control strategy consists of a number of agents working together to achieve individual objectives based on their local environment. These agents represent various types of physical (e.g. conveyor) or cyber (e.g. work order) components present in an industrial environment. Since each agent makes a decision based on the information obtained from the local environment, the system is able to adapt to unexpected problems in a manufacturing system. Although the system flexibility improves, the performance of the entire system might suffer as none of the agents have a global system view. The structure and communication of each agent must be constructed in a way that can enable system flexibility, while still being able to meet the global objectives of a manufacturing plant.



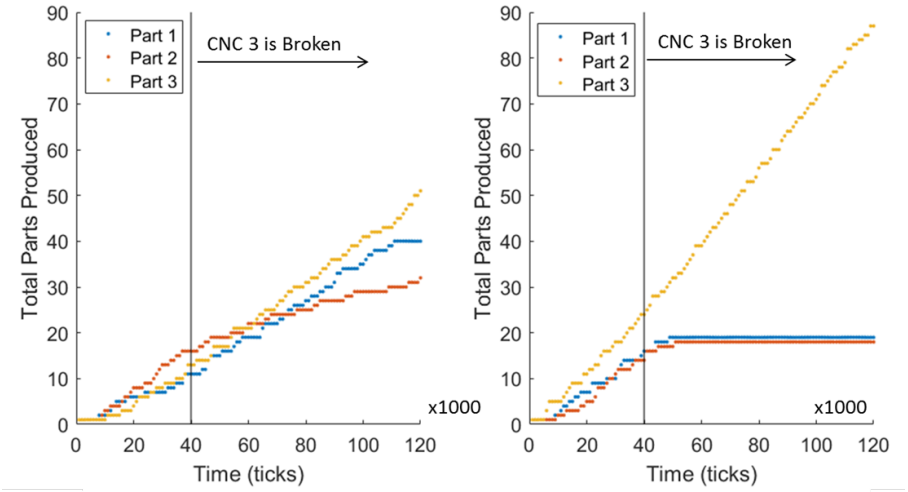
Overview of an Example Multi-agent Architecture for Manufacturing System Control

Agent-based Manufacturing System Control

Once the interfaces and APIs of each agent are defined, algorithms can be designed to improve the performance of each agent. These algorithms should be able to dynamically make decisions based on the agent's local environment, coordinate with other agents, and take advantage of learned knowledge of various parts of the manufacturing system. These algorithms can be adapted from other fields that implement multi-agent control, such as multi-vehicle systems, power systems, or autonomous robots.

Finally, the multi-agent framework must be evaluated based on manufacturing system performance. The multi-agent controller will be tested in virtual and real environments. The System-level Manufacturing and Automation Research Testbed (SMART) will be used to implement an agent-based control scheme and to validate the developed multi-agent architecture. The performance of the multi-agent control strategy will be compared to other types of manufacturing system control architectures.

We expect the multi-agent controller to be more flexible and adaptable compared to other methods of manufacturing system control. We hope to improve and better understand the system performance by analyzing and tuning the behavior of each type



Adaptability of the Multi-agent Controller in a Partially Operational Manufacturing System

DELIVERABLES

- ✓ The structures and APIs of the different types of manufacturing agents
- ✓ Control algorithms that enable agents to make intelligent decisions
- ✓ A validated framework that integrates the agents in a generalized manufacturing system

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CURRENT STATUS

- An architecture and APIs for the product agent was developed (11/2016)
- A simulation of SMART was used to test intelligent product agents (03/2017)
- A simulation of a larger manufacturing system was developed (08/2017)
- A resource agent bidding mechanism was developed and tested (09/2017)

FUTURE MILESTONES

- Develop the architecture and APIs for other types of agents in this system (03/2018)
- Implement a multi-agent controller in SMART (04/2018)
- Test and compare the multi-agent controller performance over traditional, centralized methods of manufacturing system control through mathematical analysis, simulations, and utilizing SMART (12/2018)

REFERENCES

Kovalenko, I., Barton, K., Tilbury, D. ,"Design and Implementation of an Intelligent Product Agent Architecture in Manufacturing Systems," *in* 2017 IEEE 22nd International Conference on Emerging Technologies and Factory Automation (ETFA), 2017.