Modeling and Control for Manufacturing Intelligence

Improvement of Manufacturing Systems Operation Using Cloud Services

PROJECT OBJECTIVE

Develop a framework for modeling manufacturing machines as Cyber-Physical systems to support anomaly detection and multi-objective optimization using “Big Data” and “High Performance Computing”

MOTIVATION AND CHALLENGE

Performance metrics such as Overall Equipment Effectiveness (OEE) indicate that many plants operate below 50% of their estimated capacity. Recent developments in machine communication, data extraction, and cloud computing can help improve manufacturing systems operation by providing the means to study machines as Cyber-Physical systems (CPS). We propose modeling machines and systems based on plant floor data to gain insight into productivity, quality, energy consumption and machine health. Moreover, by simulating different scenarios and evaluation of operational trade-offs our framework supports multi-objective optimization. Some of the challenges of our approach are modeling machine-part and machine-machine interactions, including performance coupling of different aspects of manufacturing quality/quantity/reliability/sustainability, and developing a data gateway and processing strategy for different analytical models.

BENEFITS

- ✓ Formulate multi-objective optimization of manufacturing systems to improve throughput, quality, reliability and sustainability.
- ✓ Provide a framework for modular hybrid models at machine and system level to support real-time simulation and analysis.
- ✓ Develop data extraction, transformation, and load strategy to process “Big Data” from a manufacturing plant floor.

OVERVIEW OF THE WORK

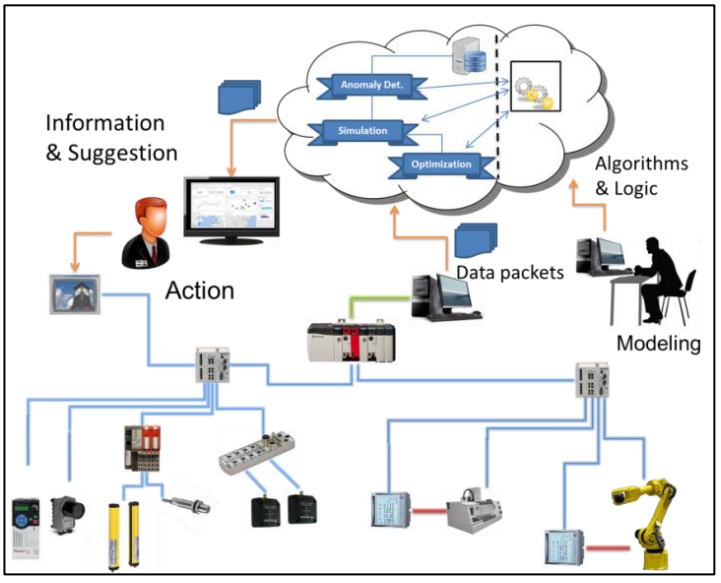
Improvement of manufacturing systems operation requires understanding of how different aspects such as productivity, quality, reliability, and sustainability interact at a machine and system level. Study of manufacturing systems as cyber-physical systems can help improve modeling, simulation, and control of different variables and support anomaly detection and multi-objective optimization. The proposed solution aims to help improve manufacturing systems in the following ways:

- Provide a framework to model cyber-physical systems in manufacturing for anomaly detection and reliability analysis.
- Develop modular hybrid model at machine and system level to support real-time simulation.
- Formulate multi-objective optimization of manufacturing systems operations.
- Study different strategies for extraction, transmission, and load, of plant floor data.

PROJECT DESCRIPTION

Our goal in this project is to optimize productivity of manufacturing systems while considering maintenance of the equipment and energy usage. To accomplish this goal, we will develop modular hybrid models of the different components in the manufacturing system. Taking advantage of the large amount of operational data that is being produced and pushed to the Cloud, we will develop automatic methods to extract the parameters for these models from real-time data streams. Finally, we will develop anomaly detection based modeling machines as CPS and optimization functions that can encode the tradeoffs between productivity, energy usage, and maintenance. The developed models are used to solve for the optimal machine parameters to improve system performance.

This research will transform the state of the art of manufacturing, enabling a high degree of maintenance scheduling and customization to meet the ever-increasing demands of manufacturing operators. The generated knowledge on hybrid modeling and multi-objective system optimization for manufacturing systems will lead to a new paradigm of intelligent manufacturing through effective and efficient monitoring and control with the Cloud.

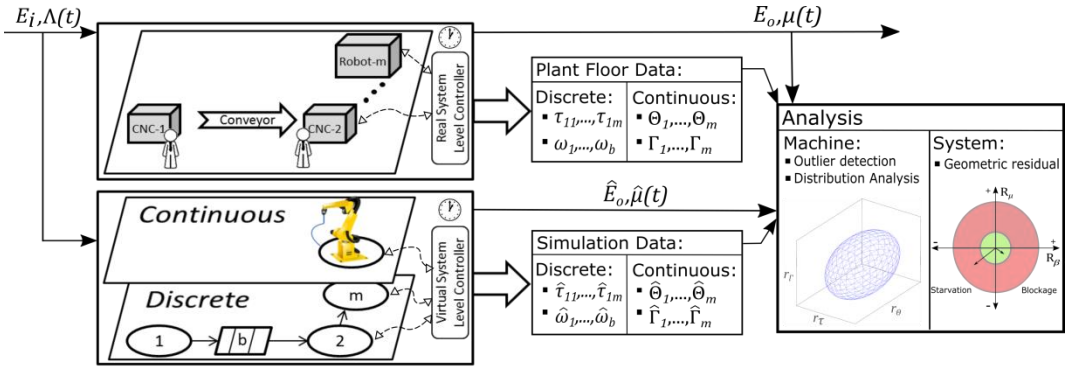


Data Pathway and Solution Architecture

Improvement of Manufacturing Systems Operation using Cloud Services

This research will lay the foundation towards a completely Cloud-based manufacturing operation. The key enabler of our research is the demonstrated industry trend that more and more data is being collected in manufacturing plants every year, and that this data is beginning to be pushed to the Cloud. Traditionally, this data was stored in local databases, queried by manufacturing engineers, who used basic tools to analyze trends, and then adjusted machine parameters for a local optimization. In emerging practice, this data is stored in the Cloud, for wider accessibility (beyond the local plant floor). Dashboards can be created that increase visibility into the plant-floor processes, both for the plant floor engineers and operators as well as for managers and supervisors across the enterprise. Based on the observed trends, users are expected to use this information to make changes in the production line through evaluating key performance indicators.

These dashboards can contain alarm-generating rules based on real-time data collection to allow rapid reaction to previously observed anomalous conditions. In current practice, however, there is no automated approach to create formal, mathematical models with this data, or to use this information to automatically "close the loop" onto the production floor. Our strategy is to use a human operator to "close the loop" by providing information and suggestion to support control action and decision making.



Framework for performance analysis and anomaly detection of cyber-physical systems using simulation

DELIVERABLES

- ✓ Framework for anomaly detection and diagnosis based on controller data for non-stationary process
- ✓ Multi-objective optimization algorithm to improve manufacturing performance metrics
- ✓ Hybrid simulation modeling strategy for machine and system level performance analysis

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CURRENT STATUS

- Real-time hybrid simulation model developed and tested (12/16)
- Framework to model machine-part interaction developed and tested (03/17)

FUTURE MILESTONES

- Develop data enhanced model based on physic-based model and plant floor data to anomaly detection (09/17)
- Create multi-objective optimization algorithm with variable weight in cost function (12/17)
- Implement machine and system level simulation to support Manufacturing Execution System (MES) using the cloud (03/18)

REFERENCES

[1] Sáez, M., Maturana, F., Barton, K. and Tilbury, D., "Real-time hybrid simulation of manufacturing systems for performance analysis and control". In *Automation Science and Engineering (CASE), 2015 IEEE International Conference on* (pp. 526-531)