Integrated Reconfiguration and Maintenance Decision Making

Research Assistants

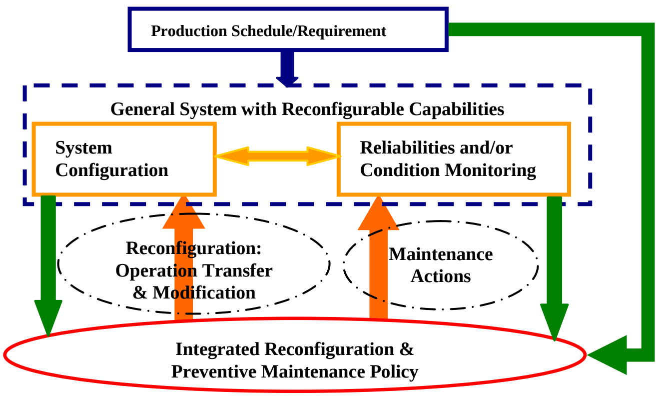
J. Zhou

Faculty:

J. Ni, J. Ivy, D. Djurdjanovic

Objectives

- To develop intelligent, cost-effective maintenance policy incorporating reconfigurable capabilities into preventive maintenance actions
- To investigate the advantages of the integrated policy over the conventional preventive maintenance policies
- To develop framework and methodologies to model and optimize the proposed integrated policy



State-of-the-Art

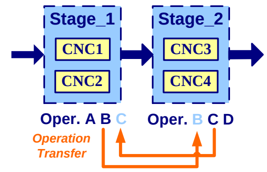
- Maintenance and reconfiguration decisions are always made separately
- Most of the existing maintenance policies deal with fixed system without reconfigurable capabilities
- Reconfiguration policies with consideration of failure and degradation do not give any instructions on maintenance actions

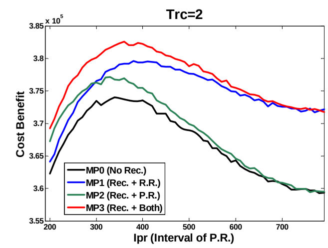
Accomplishments

- Developed the maintenance policies incorporating reconfiguration into age-based and condition-based preventive maintenance actions
- Verified the advantages of the Integrated Reconfiguration & Age-based Maintenance (IRABM) policy and optimized this policy through combined discrete-event simulation & Simulated Annealing for a simple system
- Developed the methodology to model the Integrated Reconfiguration & Condition-based Maintenance (IRCBM) policy and proposed a heuristic "control-limit" policy for a load-share simple system

Approaches

Example for IRABM





Policy Definition

> Reactive repair
> Preventive repair
> Reconfiguration
~ Concomitant of repairs only
~ Operation transfer

Decision Making

> Optimal I_{pr} – interval for preventive repair
> To which repair reconfiguration is accompanying

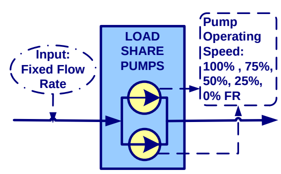
Advantages of IRABM

> More cost effective (larger cost benefit)
> Less frequent preventive repair
> Less system failures

Policy Optimization

> Discrete Event Simulation
> Heuristic Methods (e.g. GA/SA)

Example for IRCBM



Modeling Structure

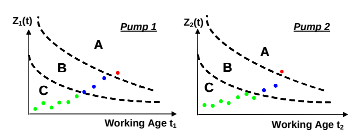
> Proportional Hazard Modeling (PHM) to include both age and condition monitoring information

$$h(t|Z_1(t),\dots,Z_m(t))=\left(\frac{\beta}{\eta}\right)\left(\frac{t}{\eta}\right)^{\beta-1}e^{\gamma_1 Z_1(t)+\dots+\gamma_m Z_m(t)}$$

> Markov process to describe the behavior of condition indicators (e.g. bearings vibration level)
> Transition probabilities are functions of pump operating speeds

Heuristic IRCBM Policy

> Policy Output – "Control Limit" Curves



> Policy Rules
~ If any pump is in A Region, replace it
~ Else if two pumps are in the same regions, set the share as (50%, 50%)
~ Else if pump1 in B, pump2 in C, set to (25%, 75%)
~ Else pump1 in C, pump2 in B, set to (75%, 25%)

Future Work

- Extend the results for IRABM policy to a general system including buffers, with critical buffer contents considered as decision variables
- Solve the IRCBM problem analytically or through simulation-based optimization to get the "control-limit" policy for the simple system
- Extend the result for IRCBM policy to a general system with complex configuration and multiply types of reconfigurations
- Demonstrate the developed policies in real-life case studies

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu

Short-term supervisory control on production system

Research Assistants/Staff: *L. Li*

Faculty: *J. Ni*

Objectives

- To detect the dynamic bottlenecks based on the instantaneous data
- To better utilize the finite resource in the plant and reduce the total cost
- To improve the system performance by mitigating the bottlenecks
- To achieve near-zero-downtime production operation in the manufacturing system

State-of-the-Art

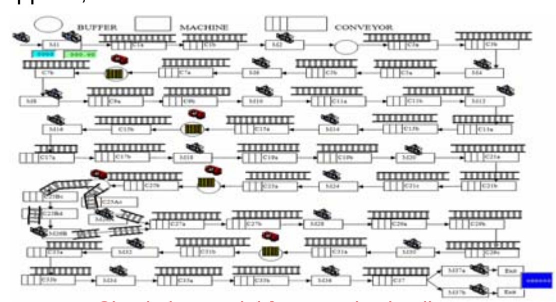
- The traditional bottleneck detection method is based on the assumed statistical behavior, which is good at long term prediction, but cannot solve the problem in short term. Furthermore, the simulation method can solve the bottleneck detection problem in both long term and short term. However, the disadvantages including long time spent, less flexibility and poor accuracy greatly impede the implementation of the simulation method. The proposed data driven bottleneck detection method can utilize the real-time data instead of statistical assumption to quickly, effectively and correctly detect bottleneck. Both simulation and analytical method are used to verify the proposed work.
- Based on the quick and correct result of bottleneck detection, the supervisory control policy will analytically make decisions on how to reduce the downtime and move buffer content to improve the system performance replacing the traditional experience-decided decision making method.
- No reliability problem has been considered in calculating the maintenance opportunity window (MOW), which will lead to the breaking down of the production operation. The proposed work will create unified risk-based MOW calculation method to achieve more stable and useful windows for maintenance.

Approaches

- Analyze the characteristics of the bottlenecks in the manufacturing and identify the bottlenecks from the data driven of the instantaneous data output in short term.
- The result of data driven bottleneck detection is the feedback control signal integrated into the supervisory control framework. Then based on the location and rank of the bottleneck, the decisions as downtime reduction and buffer initialization will be made to improve the system performance.
- Simulation is the tool for analysis and verification
- The modified proportional hazards model (M-PHM) is used to analyze the historical reliability data to predict the possibility of failure in future to achieve better result of MOW.

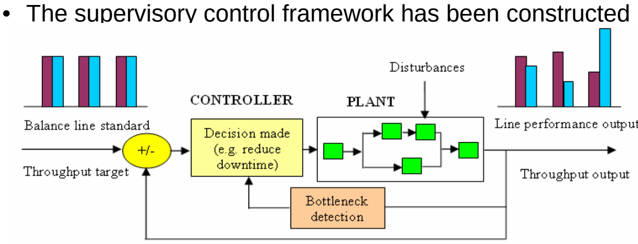
Accomplishments

- The simulation-based bottleneck detection method is applied, summarized and evaluated.



Simulation model for a production line

- The data driven bottleneck detection method has been created based on real data. Both simulation verification (over two hundred cases) and analytical verification have been performed.
- The supervisory control framework has been constructed



Supervisory control framework

- Downtime reduction control policy has been analytically constructed and the experiments in simulation show great system performance improvement.

Future Work

- Develop buffer initialization method to mitigate the bottleneck.
- Apply the proposed work in real production systems
- Develop modified proportional hazards model (M-PHM) to analyze the reliability.
- PM task dispatching and optimization

Sponsors

- General Motors Corporation. Membership for the Center of Intelligent Maintenance System

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu

Optimization control algorithms in flexible plant-floor systems

Research Assistants/Staff: *Chaoye Pan*

Faculty: *Dragan Djurdanovic, Jun Ni*

Objectives

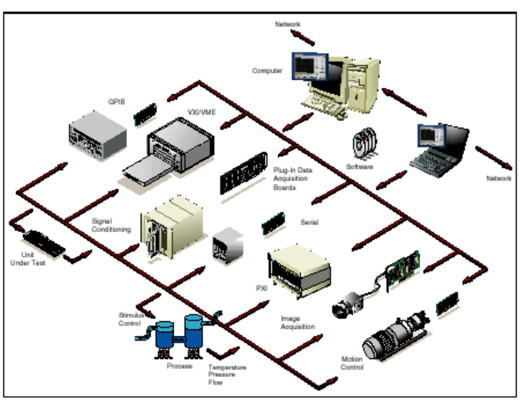
•Build up flexible Virtual Launch and Manufacturing, Plant-floor Systems to simulate the real environment

•Search for control algorithms to efficiently strengthen the manufacturing capabilities.

•Develop novel models, and tools that can be implemented in current or future plant-floor systems

Key tasks

-Generate innovative ideas and conduct research programs in the area of control design and validation of plant-floor systems and controls with emphasis on real-time sensing and control for automotive manufacturing plants
- Execute technical assignments in a resourceful, solid, and timely manner with minimal supervision
- Maintain state-of-art technical skills and knowledge
- Proposes and evaluates exercisable solutions for multilevel/multi objective optimization of complex systems

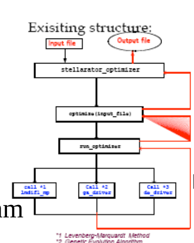


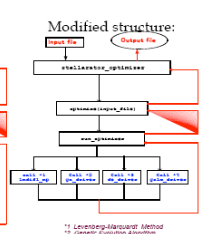
Flexible control in real plant-floor systems

Approaches

Genetic Algorithm:

Take advantage of the global parameter space search of the evolutionary algorithm

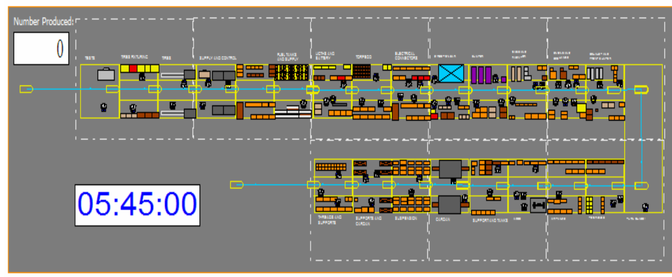




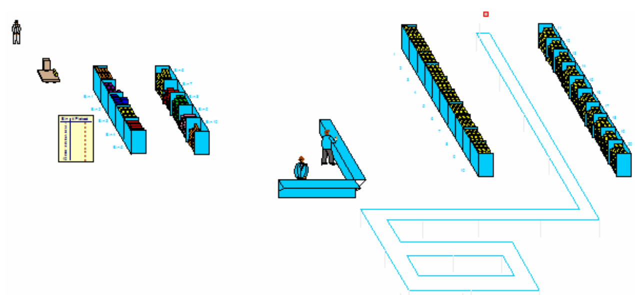
Game theory :

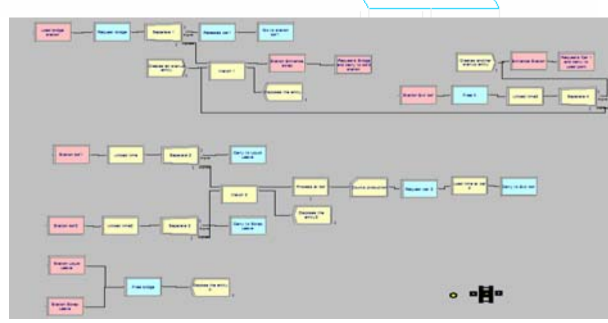
Quite useful form forms for imperfect information system ,since the real data simulation not every parameters are known before hand.

Work in progress



Build up the Virtual car assembly system





Optimize the virtual parts distribution strategy

Future work

•Build up a flexible system model to simulate the real-time situation with changing requirements

•Check the proper control algorithms for improve and upgrade its manufacturing systems core capabilities

Sponsors

- General Motor

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu

Maintenance Scheduling based on Predicted Machine Degradation

Research Assistants/Staff:

S. Lee, P. Kumar

D. Djurdjanovic

Faculty:

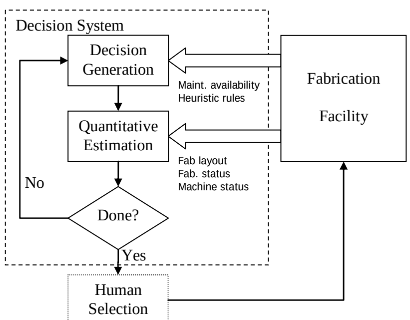
J. Ni

Objectives

- To develop enhanced maintenance schedules by considering the current and predicted equipment degradation to maximize cost-benefits
- To apply genetic algorithm to system of machines having variable throughput.

State-of-the-Art

- Current maintenance system cannot meet all the demands needed. The most eminent limitation is the use of strong assumptions in the existing work. However, semiconductor fabs are highly complex systems.
- The prognostic information is used to derive enhanced maintenance decision in order to achieve high system level yield.

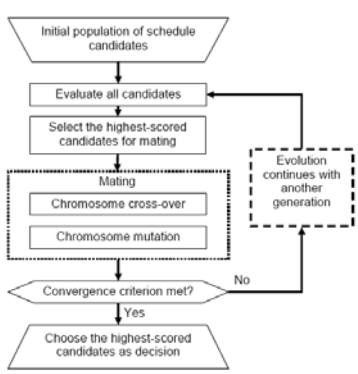


Approach

- Operation of the manufacturing process at any time moment is represented through a corresponding system state.
- The cost-effects of a maintenance schedule can be quantitatively evaluated by a cost function V = P – M

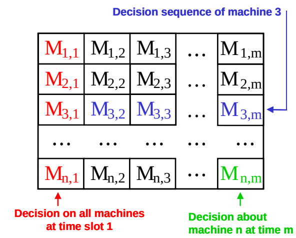
  (P: the profit gain from production activity,

  M: the cost incurred by maintenance)
- Genetic Algorithm (GA) can search for a schedule associated with the most favorable cost.

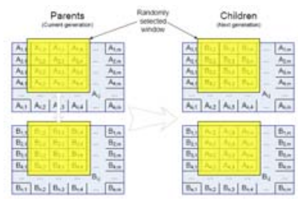


- Matrix Chromosome

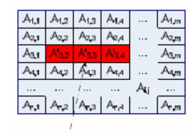
  For a system having N machines that can be maintained and whose throughput can be changed in M discrete time-moments.



- Chromosome crossover and mutation operation



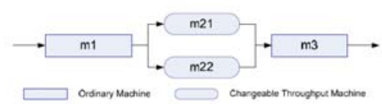
block crossover



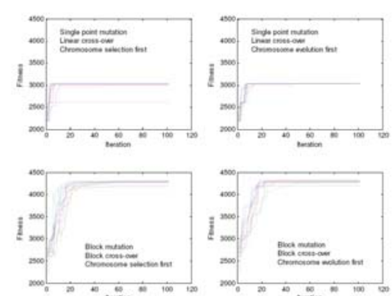
single block mutation

Accomplishments

- The performance is validated with simulation results by using the following layout



- Block crossovers and mutations enable GA to escape the local optima and find better solutions at the expense of longer evolution necessary to achieve the convergence



Future Work

- Create a flexible format for maintenance cost function in general
- Incorporate reconfiguration into maintenance schedule
- Explore specialized evolution operations and population generation for Genetic Algorithm to achieve better convergence.

Sponsors

- This research is supported by the Semiconductor Research Corporation.

For more information, contact Prof. J. Ni; Phone: 734-936-2918; Email: junni@umich.edu