A Decomposition Method to Support Evaluation and Continuous Improvement of Reconfigurable Manufacturing System Performance

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   1.2 Goal

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   2.1 Innovative Issues

3. Application to Scania Case
   3.1 Real System
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   3.4 Performance Evaluation
   3.5 Sensitivity Analysis
   3.6 Performance Optimization

4. Conclusions
Introduction

PROBLEM DEFINITION

- Systems for automatic manufacturing data collection are commonly used in real production lines.

- A big amount of production data is available in company databases but rarely this information are used for evaluating and improving the performance of the system.

- Shop floor data collection is fundamental in order to obtain a feedback from the system but information are useless if no analysis tool is available.

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GOAL

- A general framework for manufacturing system configuration, re-configuration and improvement is presented.

- Analytical models are used instead of simulation in order to ensure:
  - a deeper understanding of the system dynamics
  - short evaluating times and necessity of a few input data
  - higher possibility of reusability by the company itself.

- The framework is presented through the application to a real industrial case.

Proposed Framework

- The methodology, based on approximate analytical methods [5], aims at:
  - identifying the main causes affecting system performance
  - providing solutions to reduce the impact of these phenomena

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Proposed Framework

INNOVATIVE ISSUES

- The proposed methodology represents an high added value approach for manufacturing systems performance improvement.
- The evaluation is performed through consolidated and accurate techniques based on real data collected directly from the workshop.
- Improvement actions are defined analytically and tested on the model before being implemented.
- It can be run different times during the system life cycle in order ensure the system competitiveness in a continuous improvement perspective.
- It also supports configurations and re-configurations problems that are more and more frequent in nowadays variable environments.

Application to Scania Case

REAL SYSTEM – D12 BLOCK LINE

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**REAL SYSTEM – D12 BLOCK LINE**

- Semi-automatic transfer line composed of 22 NC stations and a final quality control
- Milling and light assembling operations starting from casted blocks
- Working 24 hours/day (three 8-hours shifts), Monday-Friday

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**REAL SYSTEM – MONITORING SYSTEM**

**Engine Block Line**

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REAL SYSTEM – MONITORING SYSTEM

Engine Block Line

Casted block

Components

Kanban system

Quality parameters

Process control system

NC machining stations

Equipment

Workers

Process data collection system

Finished engine block

Process data collected

Webserver

Dataserver

Machines

Users

Internet

Database

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DATA COLLECTION & ANALYSIS

- Failures with a duration less than 3 minutes are not classified:

- Truncated distributions have been used to account for lacking information.

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DATA COLLECTION & ANALYSIS
- Example: MTTFs and MTTRs – Tool failure

SYSTEM MODEL
- The line is modeled with the analytical method proposed in [6]

**Application to Scania Case**

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**PERFORMANCE EVALUATION**

- Average TH estimation:
  
  \[ \text{Error} = 3.65\% \]

- Average Buffer level, WIP, Lead Time and Value Added Rate estimation:

\[
\text{Average WIP (Avg, WIP)} = \sum_{i=1}^{k} \bar{m}_i + TH \times k
\]

\[
\text{Value Added} = \frac{\sum_{i=1}^{b} CT_{ai}}{Av.ELT} = 15.82\%
\]

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PERFORMANCE EVALUATION

- Average Buffer level, WIP, Lead Time and Value Added Rate estimation:
- Blocking and Starvation probability for each operation:
- Causes for Blocking and Starvation for every operation:

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Conclusions
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SENSITIVITY ANALYSIS

- How much does TH increase if we reduce by 15% the MTTR of a particular disruption type?

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Increase in TH [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 mechanical</td>
<td>0.73 %</td>
</tr>
<tr>
<td>180 others</td>
<td>0.70 %</td>
</tr>
<tr>
<td>060 electronic</td>
<td>0.47 %</td>
</tr>
<tr>
<td>060 mechanical</td>
<td>0.22 %</td>
</tr>
<tr>
<td>115 others</td>
<td>0.16 %</td>
</tr>
</tbody>
</table>

Note that we are decreasing the MTTR of a single disruption out of 141 and the action is zero cost.

- And reducing by 15 % the cycle time of the 8 slowest station?

Increase in TH = 4.65 %

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PERFORMANCE OPTIMIZATION (BUFFER ALLOCATION)

- How much does TH increase with an optimal allocation of the current buffer capacity?

TH increases by + 7.32 %
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PERFORMANCE OPTIMIZATION (BUFFER ALLOCATION)

<table>
<thead>
<tr>
<th>APPROACH</th>
<th>DELTA</th>
<th>TH</th>
<th>Tot. Buffer Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual “constrained”</td>
<td>+ 7.52%</td>
<td>= 0</td>
<td></td>
</tr>
<tr>
<td>Dual “NOT constrained”</td>
<td>+ 16.87%</td>
<td>= 0</td>
<td></td>
</tr>
<tr>
<td>Primal “constrained”</td>
<td>= 0</td>
<td>- 10%</td>
<td></td>
</tr>
<tr>
<td>Primal “NOT constrained”</td>
<td>= - 0</td>
<td>- 33%</td>
<td></td>
</tr>
<tr>
<td>Primal “target – NOT constrained”</td>
<td>+ 19.30%</td>
<td>+ 7%</td>
<td></td>
</tr>
</tbody>
</table>

- Buffers allow high increments in TH → Modular Buffers
- Long conveyors are installed for maintenance and layout reasons, but they represent a relevant cost in terms of WIP and equipment.
- It is possible to obtain relevant increments in TH without any additional buffer and without any improvement in machine efficiencies.

PERFORMANCE OPTIMIZATION (REPAIR CREW ALLOCATION)

- The line and the repair crew are modeled as 2 independent queuing systems:
- The maintenance staff strongly affects the system performance
- Usually it is the first aspect on which companies act.

TIME TO REPAIR

- Waiting time for the repairman
- Pure time needed to fix the machine

Extension and implementation of the machine interference problem

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Reference:

- The line and the repair crew are modeled as 2 independent queuing systems:

\[
\frac{1}{T_i} = \frac{1}{\lambda_i} - (1 - \delta)\frac{1}{\mu_i}
\]

- How much does TH increase with a better allocation of the current number of operators?
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PERFORMANCE OPTIMIZATION (REPAIR CREW ALLOCATION)

- How much does TH increase with a right number of operators? 

TH increment = 2.7%

Conclusions

- A new knowledge-based framework for intelligent monitoring and manufacturing system performance improvement has been developed.

- The application to a real case highlighted its potentiality and how substantial increase in throughput can be achieved with relative little efforts.

- The approach is designed in order to be run repeatedly during the system lifecycle in order to ensure its competitiveness in terms of performance.
Thank you