Optimization of an automotive manufacturing system design with regional requirements

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ProRegio

What is it?

System-level configuration optimization integrated with performance evaluation modules within the context of modeFRONTIER software.

Goal:

✓ Propose a faster manufacturing system design procedure, to study more potential configurations in less time.
✓ Considering different regional requirements regarding system design and functionality.
✓ Implement this procedure in a manufacturing system design platform.

Configuration Optimization

New Product Introduction Process

— Proposed approach
— Traditional approach
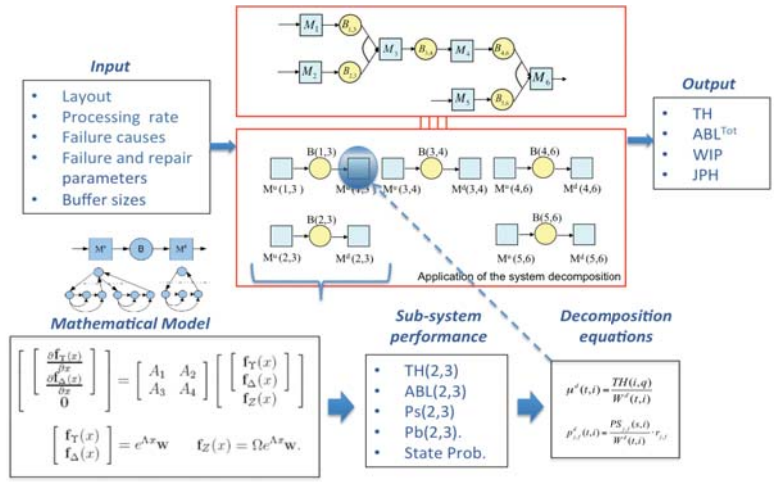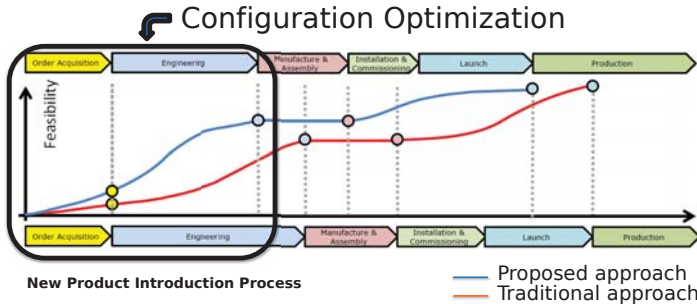
Key results & Impacts:

✓ Reduce design time under region dependent conditions, with first-time-right design (from 2-3 months to 1 week).
✓ Integrated platform for knowledge-based system design enabling knowledge re-use.
✓ Design systems under region dependent requirements and frugal innovation.
✓ First time right designs and fast quoting.

What does it do?

The system configuration has been evaluated using two different modules:
✓ A new developed **line balancing** algorithm;
✓ A proper tailored **performance evaluation** tool.

Both modules are within a **configuration optimizer**, that is a single modeFRONTIER workflow that handles the overall execution of the optimization process, providing:
✓ Multi-objective optimization on:
  ❑ Production, inventory and operative costs;
  ❑ Line actual productivity (i.e., OEE and JPH);
  ❑ Energy consumption;
  ❑ Cycle times.
✓ Generation of optimized candidate solutions (Pareto frontier).
✓ Precise calculation of system performance, considering reliability and buffers.
✓ Robustness analysis and Discrete Event Simulation on Pareto solutions.
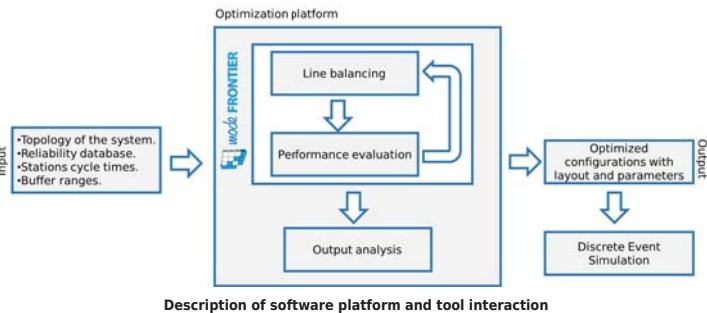
Description of software platform and tool interaction

Input and layout

The starting information needed by the optimization is:
✓ Topology of the system.
✓ Reliability database.
✓ Stations cycle times.
✓ Buffer ranges.
✓ Regional variants.
✓ Operational and investment costs.

Performance evaluation

The optimization is based on a mathematical model, based on Markov chains that works as evaluation kernel, providing:
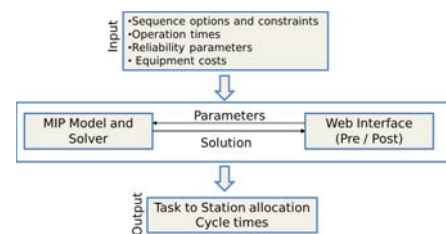✓ Fast configuration evaluation.
✓ Actual and detailed line KPIs estimation, like OEE, Jobs per hour (JPH), Work in progress, etc.

Input
- Layout
- Processing rate
- Failure causes
- Failure and repair parameters
- Buffer sizes

Output
- TH
- ABL^{Tot}
- WIP
- JPH

Application of the system decomposition

Mathematical Model

$$\begin{bmatrix} \frac{\partial f_T(x)}{\partial x} \\ \frac{\partial f_\Delta(x)}{\partial x} \\ 0 \end{bmatrix} = \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \begin{bmatrix} f_T(x) \\ f_\Delta(x) \\ f_Z(x) \end{bmatrix}$$

$$\begin{bmatrix} f_T(x) \\ f_\Delta(x) \end{bmatrix} = e^{Ax}w \qquad f_Z(x) = \Omega e^{Ax}w.$$

Sub-system performance
- TH(2,3)
- ABL(2,3)
- Ps(2,3)
- Pb(2,3).
- State Prob.

Decomposition equations

$$\mu^x(t,i) = \frac{TH(i,q)}{W^x(t,i)}$$

$$p^x_{r,i}(t,i) = \frac{PS_{r,i}(s,i)}{W^x(t,i)} \cdot r_{r,i}$$

Description of the developed analytical method.

Line balancing

Mixed Integer Programming model and solver:
✓ Handles complex constraints (e.g. specific constraints among tasks as precedence)
✓ Provides a true optimal balanced configuration

Optimization objectives
✓ Difference between station times minimization
✓ Equipment cost minimization

Input
- Sequence options and constraints
- Operation times
- Reliability parameters
- Equipment costs

MIP Model and Solver
Parameters / Solution
Web Interface (Pre / Post)

Output
Task to Station allocation
Cycle times

Schematic representation of the line balancing tool

Application to Comau case study: cylinder head assembly

The methodology has been successfully used in the configuration of an automotive assembly line of Comau, including the regional variants and costs.

✓ Increasing Demand in Growing Countries
✓ Relatively well-known product and process
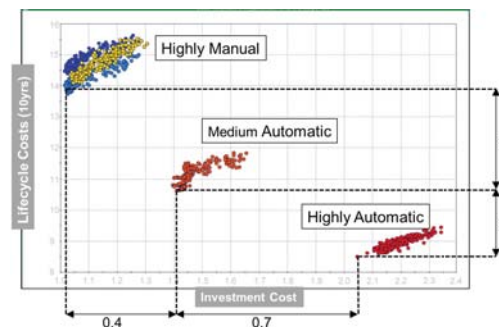✓ Different Levels of Automation, according to the specific regional requirement.

Example of process chain and cylinder head assembly

OP50	
20120	Press valve stem seals
20120/1	[Manual]
20120/2	[Auto with robot]
20120/3	[Auto with gantry]
20150	Assemble valve springs
20150/1	[Manual]
20150/2	[Auto with robot]
20150/3	[Auto with gantry]
20160	Assemble valve spring retainer
20160/1	[Manual]
20160/2	[Auto with robot]
20160/3	[Auto with gantry]

20150/1   20150/2   20150/3

Example of operation alternatives

The optimization platform generated a set of solutions for different plant locations, according to the specific regional requirements.

Highly Manual
Medium Automatic
Highly Automatic

Configuration alternatives for EMEA region, considering different levels of automation while respecting all technological requirements.

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