The Use of Predictive Intelligence to Optimize System Availability

NDIA Conference
October 31, 2013
Innovation… A Backbone for Continued Success
The Challenge

- Modern way of life is driven by Manufactured products that transport us, allow to produce goods and produce energy that supports the process.

- Model is limited unless we can:
  - Preserve energy
  -Extend the life cycle of equipment
  - Use equipment constantly at peak performance
Solution......Technology to the Rescue!

- Extended – Product Life Cycle Management (PLM)
  - Beyond design of products and processes
  - Present visibility into the complete lifecycle of a product
  - “Product-in-Life” model – History of maintenance ops, part repairs, part breakdown occurrences.
Creates new challenges

- Lack of Data Collection strategies
- Disparate systems
- “Big data” is difficult to leverage w/o proper data analysis tools
- Classical SPC is limited
- Machine learning introduced:
  - Neural Networks and Vector Support Machines= Predictive views
  - Decision Trees and Rules inference = Explanatory
From simple processes to highly sensitive multivariate processes

<table>
<thead>
<tr>
<th>Linear</th>
<th>Complex</th>
<th>Highly Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreadsheet</td>
<td>Specialized Learning Algorithms</td>
<td>Real-time Dynamic Process Control</td>
</tr>
</tbody>
</table>
Unpredictability increases with complexity

- Potentially dozens or hundreds of functional steps, each with multiple parameters
- High influence of the disparate characteristics (physical properties, formulation, composition, expiration, storage times and conditions)
- High influence of the operating conditions (product or process specifications) and the environment (humidity, temperature, etc.)
- Chemical reactions are highly non-linear, non-reversible phenomena and very difficult to predict
- Because of the highly multivariate and non-linear nature of the events, Theoretical Models and Statistical Process control are not effective to predict and eliminate failures.
WHEN TO APPLY OPERATIONS INTELLIGENCE:

WHERE COST OF FAILURE IN PRODUCTION (REWORK, SCRAP) OR OPERATIONS IS HIGH (FIELD FAILURE)

1. High Engineering Content
2. Small Batch runs or unique end items
3. Highly variable process
4. Complex Configuration Management
DELMIA OI within Data Mining / Analytics Landscape

Data Mining Techniques

User-Based Analysis
- OLAP, Business Intelligence
- Visualization Methods

Automatic Analysis
- Implicit
  - k-Nearest Neighbors
- Case-Based Reasoning

Explicit
- "White Box" Models
  - Classification
  - Regression
  - "Black Box" Models
  - SVMs
  - Neural Networks
- "White Box" Models
  - Unsupervised
  - Supervised
  - Association Rules
  - Bayesian Networks
  - Decision Trees
  - Rule Induction

Optimization Techniques
- Such as Genetic Algorithms

Statistical Models
- Correlation Analysis
- Factor Analysis
- Logistic Regression

Data Mining techniques allowing knowledge extraction
Temporary adjustments to controllable parameters
Release constraints when context allows it
### LEARNING by EXPERIENCE

<table>
<thead>
<tr>
<th>Resin Rate</th>
<th>Temperature</th>
<th>Vacuum</th>
<th>Autoclave #</th>
<th>RESULT</th>
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### FINDING PATTERNS

NO STATISTICS, NO EQUATIONS, NO MATHS

JUST LOGIC
A complement to Statistics for the most complex situations

### OI Learning Engine

**ANALYZING THE LINES OF THE TABLE**

Process Parameters (values)

<table>
<thead>
<tr>
<th>Production Batches</th>
<th>A</th>
<th>B</th>
<th>C</th>
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Logical (Non-Statistical) Analysis: Looking for common patterns among batches, independently of number of variables

**PERFORMANCE**

- Learning from the end tails

### Statistical Tools

**ANALYZING THE COLUMNS OF THE TABLE**

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Statistical Analysis: Looking for trends and correlations among parameters, independently of number of samples

**PERFORMANCE**

- Creating a model for the normal behavior
Overview of the Operations Intelligence Algorithms

Data Preparation
- Experiment Plans
- Correlations
- Curve pre-processing
- Histograms (number of bars), graduations

Study Preparation
- Discretization
- Multi-objective output definition
- Explanatory potential
- Determination of the most influential variables

Rule Discovery
- Learning
- Rule indicators
- Build new rule from samples
- Rule optimization
- Operations on rules and conditions

Rule Compliance
- Risk calculation
- Recommended setting ranges

Process Rules Discovery
Process Rules Discovery
Process Rules Discovery
Operations Advisor

Patented
Manufacturing Intelligence by DELMIA

Process Optimization to avoid predicted risk at lower cost

Access to Rule-based Monitoring and risk prediction for each additional batch

Analyze impact and Archive new data for Rule enhancement

Rule REPOSITORY discovered and published by the Experts, explaining in natural language the Best Practices and the Risk Zones in Production

NEW REAL-WORLD EVENTS

PERFORMANCE TRACKER™

Process Optimization to avoid predicted risk at lower cost

Access to Rule-based Monitoring and risk prediction for each additional batch

Analyze impact and Archive new data for Rule enhancement

Rule REPOSITORY discovered and published by the Experts, explaining in natural language the Best Practices and the Risk Zones in Production

OPERATIONS ADVISOR™

Rules

VARIABLES

#1 #2 #3 #4 ...

#N

QUALITY

GOOD

GOOD

BAD

GOOD

BAD

BAD

BAD

GOOD

BAD

HISTORY

PERFORMANCE RECORDS

Quantitative and/or qualitative descriptors, ordered or non-ordered

#N

Analyze impact and Archive new data for Rule enhancement
Air France Industries

Business Challenges

- Find new maintenance practices to guarantee higher levels of performance
- Reduce EGT margin variability without increasing costs
- Being able to beat industry standards and become more competitive
- Increase customer satisfaction and loyalty

Operations Intelligence

- Analyze past work scopes to identify good and bad practices
- Discover how engine modules actually interact for global performance
- Keep analysis 100% fact-based
- Produce results that can be shared with customers
Key results

- New practices were discovered, using a mix of module parameters
- New inter-module coordination at shop level
- +10° average on EGT margin levels on Airbus 340 and Boeing 747 fleet
- 1% savings on in-flight fuel flow

“Operations Intelligence has been extremely useful in identifying optimized combinations of maintenance parameters. Previously, we suspected the existence of such parameters. However, now we can identify and justify them in a very clear manner. We obtained tangible results that demonstrated a direct impact on the EGT margin. With Operations Intelligence, we are able to implement a program of continuous improvement which enables us to enrich our knowledge and to better address our customers’ expectations”

– Emmanuel Desgrées du Loû, Engine Overhaul Director, Air France Industries.
Optimized System Availability = ROI

**Input Data:**

- Engine Overhaul cost = $100 / EFH
- Average EGT increase = 3°/1000 EFH
- Average EGT penalty = $10,000 per ° below spec
- Average % of engine removal due to EGT limit: 60%
  - +5° on EGT margin creates 160,000 $ per engine in cost savings for Airlines (equivalent to 1600 additional hours on wing)
  - **ROI for a fleet of 50 engines = 160,000 $ x 50 Engines x60% = 4,8 M$ / yr**
# Operations Intelligence as a closed-loop mechanism

## PLM Backbone / Data Referential

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<th>Manufacturing</th>
<th>Services after-sales</th>
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<td>Requirements</td>
<td>Engineering</td>
<td>Design</td>
</tr>
<tr>
<td>System simulation</td>
<td>CAD</td>
<td>CAE simulation</td>
</tr>
<tr>
<td>Process simulation &amp; planning</td>
<td>Manufacturing Execution</td>
<td>Performance/ Warranty</td>
</tr>
</tbody>
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## Knowledge & Intelligence Management

- DELMIA Operations Intelligence
Changing times require new innovations
Contact Information

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