Digital, Smarter: Industry Perspectives

Smart Manufacturing– Connected Intelligence Platform Enables Insight

Presented by

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Agenda

• Smart Manufacturing Concepts
• Use Cases & Architecture
• Multivariate SPC with Demo
• Continue the Journey
• Questions
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Manufacturing has always been...

“Clever”
Challenges for Manufacturers

• Proliferation of Products: more options, shorter lifecycles, more complex products

• Agile, flexible operations
  • Easily accommodate mix shifts and new products

• Invest in Quality and Reliability

• Increase Productivity, Reduce cycle times & costs

• Maximize value obtained from factory equipment

• Global supply chains
Industry Trends - Technology

• Internet of Things and connected sensors (IIoT) in products and factory equipment
  • *Predictive maintenance, Adv. process control*
  • *Network-capable products, Edge data collection*

• Increasing use of factory robotics

• Advances in materials
  • *nano-materials, biotech, carbon fiber, ...*
  • *Batteries & Fuel-Cells for vehicles*
  • *3-D printing*

• Greater Intelligence in software used in design, manufacturing, supply chain & support
  • *Machine Learning & Artificial Intelligence*
  • *Real-time, collaborative decision-making*
  • *Social Media, Mobile, Cloud & Big Data Analytics*
Manufacturing is...

“Smart”

...Now
Connected Intelligence
Platform Architecture

Data Consumers

- Equipment
- IoT Sensors
- Business Units
- Customer Apps
- Analytics / BI

External Platform / API Management

Data Sources

- ESB
- Databases
- Legacy Apps
- MicroServices / MicroApps
- Cloud Integration
- 3rd Party SaaS / “Shadow IT”
- Streaming Data Collection
- Business Event Processing
Performance Status
Create and manage factory maps, process control workflows, early warning systems

Predictive Maintenance
“fix-as-needed” to increase asset utilization and reduce unnecessary resource consumption

Anomaly Detect + Correct
Analyze and adjust production to improve product throughput and quality

Supply Chain
Create intelligent routes to get products where they need to go efficiently

Demand Forecasting
Understand product trends to better predict manufacturing cycles

Digital Manufacturing Models
Analyze and optimize cost, cycle time, product quality without causing operational downtime

Connected IoT Networks
Link systems at the edge to provide real-time insight into operations and data
Use Case Areas

- **Performance Status Monitoring Dashboards** (Static to Real-Time)
  - Factory maps, Early Warning Systems
  - Process Control

- **Product & Process Quality Improvement**
  - Complex products & processes, big data

- **Optimal Maintenance (Predictive and Scheduled)**
  - For factory equipment and connected products in the field

- **Supply Chain**
  - Demand Forecast & Inventory optimization
  - Optimal routing: vehicles and warehouses

- **Customer Analytics**
  - Granular, detailed understanding of markets & customers

- **Operations**
  - Resource optimization

- **Digital factory models**
  - Cost, cycle time, quality ...
What Makes Manufacturing “Smart”

- **Interoperability**: Cyber-Physical Systems allow humans and smart factories to connect and communicate with each other.

- **Virtualization**: A virtual copy of the Smart Factory is created by linking sensor data with virtual plant models and simulation models.

- **Decentralization**: Ability of cyber-physical systems to make decisions of their own and to produce locally thanks to technologies such as 3D printing.

- **Real-Time Capability**: The capability to collect and analyze data and provide the derived insights immediately.

- **Service Orientation**: IoT devices communicate with each other and with other systems using a platform of reusable services.

- **Data Analysis**: Flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules.
Smart Manufacturing: Use Cases & Technology

Mike Alperin
Manufacturing Industry Consultant
Data Science Team
Visual Analytics
Machine learning algorithms

• Good Results
  • Machine learning + Big Data sets = Accurate prediction & pattern detection for complex processes
  • Hundreds or thousands of variables

• Easy to use / Simple user interface
  • Computer algorithm does the heavy lifting
  • Results visualized - easy-to-understand
Manufacturing Advanced Analytics Use Cases

Understand & Predict Product, Process, Metrology & Equipment performance
• Identify complex interactions & nonlinearities: GBM, Random Forest, Linear / Logistic Regression, Deep Learning, Principle Components, Clustering

Trends: Monitor, Alert & Predict
• Uni / Multi-variate Control Charts, Time Series Shewhart, ARIMA, Holt-Winter, Non-parametric

Pattern Recognition and Anomaly Detection
• Anomalous product, Defect image classification
  Neural nets

Resource Optimization
• Optimal Maintenance, Scheduling or Vehicle Routing
  Linear Programming, Genetic Algorithm

Reliability
• Model and Predict Failures
  Weibull, Kaplan Meier
Connected Intelligence for Manufacturing

- **Predictions Events**
  - Models & Rules Management
  - Real-time Monitoring
  - OCAP Action Flows

- **Decision Support**
- **Alert**

- **Data at Rest**
- **Streaming Data**

- **Environment, Materials, Equipment, Process, Product**
  - Data Access, Prep & Aggregation

- **OCAP**
- **Action Flows**
  - Identify Factors
  - Build Models
  - Find Patterns & Anomalies

- **Model Maintenance**

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AUGMENT INTELLIGENCE

Visual Analytics
- Spotfire
- Live DataMart

Predictive Analytics
- Statistica
- TERR
- many other engines

Machine Learning

Streaming Analytics
- Streambase
- BusinessEvents
- Live Score

Data Infrastructure

Analytics designed by data scientists

Automated Action

Continuous Visualization

Business Strategy

Spotfire Connection
Real-time Factory Monitoring

Production Monitoring

- Real time Monitoring
  - Entire Factory
  - Lines
  - Tools
  - Sensors / Metrics
- Problems Detection & Notification
- Predictive Maintenance
- Minimize downtime
IoT Equipment Monitoring Architecture

**Streambase Server**

- **RULES, MODELS**
  - If avg(temperature) in the last 5 minutes > 100C
  - And avg(pressure) in the last 10 minutes > 1000 PSI
  - Then raise alert("DANGER: Maximum Operating parameters exceeded")

**Alert**

- If min resistivity *will* drop below 28 Ohms in the next 4 hours
  - Then raise alert("Resistivity will be out-of-spec by 8:42 am")

**Liveview Server**

**Liveview Desktop**

**Integration**

Comprehensive adapters for other systems especially with open source systems, MES and SCADA
Exchange data between TIBCO products (AS/Spotfire/BW/BE/TERR)

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Solar Panel Manufacturing

• **Problem**: Multiple facilities, many processes
  • High Variability of Sheet Resistance causes lower than desired solar cell energy conversion efficiency
  • Difficult to compare production run to yield models

• **Solution**: Higher Yield, Throughput & conversion efficiency
  • Real-time resistance monitoring
  • Process Manufacturing can run tighter tolerances and adjust them mid-run, predicting yield and adjusting to changing variables
  • Network systems proactively re-route high-value customers around effected network areas in real-time

• **How We Do It**: The TIBCO Connected Intelligence Platform
  • IoT, Spotfire, StreamBase, and TERR for predictive modeling.
  • High-speed network
IoT Accelerator - Machine View
IoT Accelerator - Sensor / Metric View

Temperature

Temperature Type
- Honeywell

Last Reading
- 89.7°C

Reading Quality
- ""
Insight from Advanced Analytics: Models, Patterns & Anomalies

- Models & Rules Management
- Predictions
- Events
- OCAP Action Flows
- Real-time Monitoring
- Decision Support
- Software process Spotfire template
- Environment, Materials, Equipment, Process, Product
- Data Access, Prep & Aggregation

Identify Factors
Build Models
Find Patterns & Anomalies

Data at Rest

Streaming Data

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• Predictive analytics for Analysts and Citizen Data Scientists
• Built-in TIBCO Enterprise Runtime for R (TERR)
• Statistica Integration
• Big Data Ecosystem
Drag & Drop Workflow environment – Supports the Citizen Data Scientist

- Data Acquisition, Prep & Blending
- Model Creation
  - Comprehensive Statistica palette – stats, machine learning, text mining, image & audio
  - Algorithm Marketplaces – Azure ML, Algorithmia, Apervita, H2O
  - Open Source - R, Python, C#, Spark, H2O
- Metadata Creation
- Model Deployment
  - Monitoring and Alerting Server
  - LiveScore – realtime, IoT
- Model Management, Security & Governance
  - Version control
  - Audit logs
TIBCO Statistica to TIBCO Spotfire

Execution of Curated Predictive Models in Statistica

Triggered from Spotfire, Rendered in Spotfire

Integration: IronPython Script in Spotfire Driving Statistica Analytics

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Spotfire Custom Geospatial maps + TERR Data Functions

- TERR Wafer Map generator
- TERR data smoothing
- TERR contour + heatmaps
- Engineering plots
- Factory Floor map
- Process map
- Defect map with drill-down to image
Problem
- Product & Equipment problems difficult to accurately diagnose for complex manufacturing processes
- Big Data problem – millions of units, hundreds / thousands of predictors
- **Response**: Product, Process or Equipment data
- **Predictors**: equipment sensor, process and product measurements or attributes

Value
- Customers solving previously intractable problems.

Method
- GBM analysis template to identify significant predictors, interactions and nonlinearities
- For large datasets, hybrid data access used to perform variable reduction step in-DB
- Simple interface – easy for business analyst to run and interpret results

**GBM results for semiconductor yield as a function of in-process equipment & product measurements**
Predictive Maintenance

- **Predict:**
  - Machine outage
  - Defective product

- **Predictors:**
  - Machine sensor data
  - MES / Recipe
  - Process measurement data
  - Environmental data

**Predictive Maintenance Model from Sensor Data**

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Spotfire Big Data Architecture

Visualize

Spotfire Client

Calculate

In-Memory

In-Datasource

On-Demand

Data Connectors
Hive, Impala, Spark, Databricks Cloud, Hortonworks, Drill, HAWQ, Teradata, Aster, Netezza, Vertica

Distributed Computing
MapReduce, SparkR, H2O, Fuzzy Logix

Big Data Stores
Hadoop, Netezza, Teradata/Aster, HP Vertica

Other data stores

Nodes

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Configuration
• 13 billion rows / 4000 variables
• 24 node AWS cluster
• Cloudera Impala connector

Performance
• Results returned in under 60 seconds.
• Analysis took many hours before this soln
Big / Wide Data Yield Model – Feature Selection and Prediction

**Goals:**
- Predict yield for semiconductor manufacturing process
- Feature selection to Reduce problem dimension
- Use big data platform (Hadoop, Spark)
- Integrate Statistica & Spotfire - 1000s of users

**Problems:**
- Ultra-wide data: Thousands to Millions of variables
- Approaching 1 billion cases
- Mix of categorical and continuous predictors
- Sparse data

**Solution:**
- Spark parallel processing
- Feature selection algorithm + Lasso regression
- 1 TB Hadoop cluster: 90 cores, 1 GB RAM
- Statistica analytic workflow used to submit code to remote spark cluster and view results in Spotfire

**Performance:**
- Running time reduced to minutes
Statistica for Manufacturing

- Quality Control Charts
  - Univariate, Multivariate
- Design of Experiments
  - Screening, Response Surface, Taguchi, Optimal, Mixture
  - Multi-response profiler
- Product Traceability / Genealogy
- Process Analysis
  - Process Capability, Gage R&R
- Product Shelf-life & Stability
- Six Sigma Tools
  - Fishbone diagram, DMAIC menu
- Comprehensive Modeling Capabilities

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Process Control
Use Case Areas
- Assess Process Capability
- Process Control: Detect changes from baseline

Solutions
- Classic: Shewhart charts
- Setting & Storing Control Limits:
  - Western Electric or Nelson rules
- Advanced: multivariate, Predictive models
- Automated Alerting: Periodic or Real-time

**Individual – Moving Range Control Charts**
TIBCO Statistica to TIBCO Spotfire

SPC (Manufacturing) Modeling in Statistica

Dynamic Control Chart in Spotfire

Integration: Read and write .sbdf nodes in Statistica

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Smart Manufacturing: Model-Based SPC & Virtual Sensors

Tom Hill, PhD
Senior Director, Analytics
TIBCO Statistica Analytics Platform

Managing curated / validated workflows for standardized enterprise-wide analytics and best practices

Tom Hill, PhD
Sr Director, Analytics

- anticipate and handle disruptions
- predict impending equipment failure
- optimize routes
- prevent fraud
- real-time inventory management
- deliver proactive customer service
- smart cross-sell offers
- optimize pricing
How to: Real-time high-dimensional process monitoring for solar cell manufacturing

- Quality is determined by the output power in response to a standard (calibrated) light source.
- Is a function of the purity of silicon crystals and how they are layered onto the cells.
- Depends on thousands of data streams -- all of them have to be right.

Results:
- Real-time preventive maintenance system implemented on shop-floor
- Monitors thousands of parameters with analytic drill down
- Statistica credited as a critical competitive advantage
CONTROL CHARTING ONE PARAMETER AT A TIME

- Control charting for individual parameters
  - Model is: Mean plus some acceptable variability
MONITORING LARGE NUMBERS OF PARAMETERS

- Monitor all parameters in “real time”
- Relevant for predictive maintenance because we don’t know what will fail next
- Drill down with control charts
• Suppose we measured 2 parameters $y_1$ and $y_2$ (e.g., person’s height & \(1/\text{weight}\))
• Univariate charts would not detect some obvious outliers
• This happens in many real applications
• Also called *Virtual Sensors*
• Measure components underlying multivariate measures
• Build a multivariate model from data when process was good, in-control
• Apply that model to the ongoing process to detect
  • Shift, drift, outliers in underlying components, virtual dimensions
    *Virtual sensor is working, and senses shift, drift, or an outlier*
  • Changes in the fundamental relationships between parameters
    *Virtual sensor is no longer working*
  • Root causes among parameters, inputs
    *What specific parameters contribute most to the problem*
BUILDING, SAVING, MANAGING MODELS

- Statistica provides model management, version control, audit logs, electronic signatures, GxP compliance
DEPLOYING MODEL-BASED MSPC THROUGH SPOTFIRE

- Continuously updated data in Spotfire
- Shopfloor drilldown through outliers, special causes, alarms, etc.
BIG DATA ARCHITECTURE FOR MANUFACTURING

Data Tier
- RDBMS
- Data Historians
- Multi-dimensional (cubes)
- Web Services, REST

Server/Application Tier
- Statistica Server
- Monitoring and Alerting (MAS)

Big Data Applications
- Apache Spark
- MLlib
- H2O.ai
- elastic

Statistica Analytics User
- Browser
- Workstation

Statistica Monitoring
- Browser

Spotfire User
- Browser
- Workstation
1. Analysts create reusable Workspaces/flows (templates), models and rules, and publish them into the Enterprise Metadata Repository.

2. The Enterprise Metadata Repository manages users, data access/analysis templates, workflows, scoring models, ...

3. Analytic templates can be used for batch scoring, ad-hoc analyses, reports, ...

4. ...and for real-time scoring integrated into existing service architectures.

5. Processes/KPI’s can be monitored via MAS dashboards (alarming, alerting).

6. All templates/models are version controlled, with audit logs, signatures, ...
1. Analysts create reusable Workspaces/flows (templates), models and rules, and publish them into the Enterprise Metadata Repository

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3. Analytic templates can be used for batch scoring, ad-hoc analyses, reports, ...

4. ...and for real-time scoring integrated into existing service architectures

5. Results/data can also be delivered to applications such as Spotfire, StreamBase

6. All templates/models are version controlled, with audit logs, signatures, ...
Real-time high-dimensional process monitoring: Solar cell manufacturing

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Orchestrating Big-Data Analytics Pipelines with Statistica: Semiconductor Manufacturer

- Leading manufacturer of next-gen 3D flash memory; ramping up production
- 10’s of thousands of measured parameters, growing to millions
- Feature selection of millions of predictors of yield
- Large Hadoop cluster backend; 100+ cores; Spark/MLLib

Results:
- Statistica provides automated pipeline that pushes feature selection into Spark
- Then performs Lasso regression on in Statistica
- Writes results to Spotfire for interactive exploration by engineers
Continue the Journey
TIBCO Community Wiki: ‘how to’ support

https://community.tibco.com/wiki/tibco-spotfire-community-wiki
Download Accelerators, Templates & Data Functions

TIBCO® Exchange
Extend the capabilities of your TIBCO® products with extensions, add-ons, plug-ins, etc.

Random Forest Template for TIBCO Spotfire®

Gradient Boosting Machine Analysis Template for TIBCO Spotfire®

Anomaly Detection Template for TIBCO Spotfire®

Quality Control Charts template for TIBCO Spotfire®

Template for using XGBoost in TIBCO Spotfire®

Clustering with Variable Importance Data Function for TIBCO Spotfire®

Real-time Inventory Accelerator

Accelerator for Apache Spark

Intelligent Equipment Accelerator

https://community.tibco.com/exchange/field_product%253Afield_product_category/analytics-5506

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