Failure prediction and process monitoring using Machine Learning at MONDI Gronau

Dr. Michael Kohlert, MONDI Gronau GmbH
Elmar Tarajan, MathWorks Consulting Services
Dr. Sarah Drewes, MathWorks Consulting Services

05/2016
Plant

Mondi Gronau GmbH

Jöbkesweg 11
48599 Gronau, Deutschland

Local: ~ 850 employees
Global: ~ 25,000 employees

Mildenerger & Willing -> Nordenia -> Mondi

- Production Volume: 170 Mio. kg
- Waste Volume: 15 Mio. kg
- Number of rolls: 1.7 Mio. Stk.
- Yield: 421 Mio. €
- Energy Consumption: 71 Mio. kWh
- Production Time: 24/7 hh/dd
- Square meter: 104 k. m²
Facts & Figures: References
Facts & Figures: Machines

Extrusion Lines

- Monoextrusion
- Coextrusion: n - Layer
- Film thickness: 10 – 300µm
- Film width: 850 – 3.000mm
Facts & Figures: Machines

Processing Types

- Coating / Siliconizing
- Slitting
- Rotogravure Printing
- Lamination
Facts & Figures: Products

Benefits Mondi Gronau GmbH

Good Product

Waste Product

Benefits

- Advanced Quality Monitoring
- Reduction of Waste Material
- Customer Satisfaction
- Yield Optimization
Monitoring Systems
Monitoring: In-Line

Integrated Monitoring System

- Laminated Film Surface Detection
- Traffic Light System
- Quality Index
- Additional Systems: Colour, Thickness
Data Acquisition

- Parameters/Features (100 – 500)
- PLC (Programmable Logic Controller), Data Collector
- 4-5 PLC per machine for real-time acquisition
Data Processing
First Step in Visualization

- Acquisition
- Pre-Processing (ETL)
- Limits/ Targets from Customer Specifications
- Visualization On-Line/ Off-Line
Processing

Next Step in using Prediction Methods

- Acquisition
- Pre-Processing (ETL)
- Machine Learning Methods/ Models
- Visualization On-Line/ Off-Line

Support Vector Machine

Quality Data (OCS, Laboratory)
MES, SAP
PLC
Next Step in understandable Visualization

- Reduction of information to understandable level (1, 2, 3 dimensions)
- Visualization in real-time

Up to 200 parameters in one point [temperature, pressure, speed, …] acquired per minute stored on an Oracle database processed for visualization in lower dimensions.
Next Step in Software Development

Version 1.0 (internal)

Version 3.0 (Mathworks)

Acquisition Loop

- Acquisition of more Datasets
- Pre-Processing (ETL)
- Extended Machine Learning Methods/Models
- Version 3.0 of Visualization On-Line/Off-Line
Human-Machine-Interface
Human-Machine-Interface: Industrie 4.0

Processing Loop

- Open Processing Loop
- Recommendation System

Machine Sensory Locations

Data Stream

Field Bus PLC Data Collector TCP/IP MDE Server TCP/IP SQL Query

Manual Adjustment by worker

Machine Interface
Application requirements
Retrieve, analyze and visualize machine data

- Up to 40 machines with up to 500 sensors
- Updated once per minute - near real time
- Alarm events and error logging
- Intuitive user interface
- High robustness
- Expandability
- Failure forecasts for increased quality / downtime reduction
Application requirements
Retrieve, analyze and visualize machine data

- Up to 40 machines with up to 500 sensors
- Updated once per minute - near real time
- Alarm events and error logging
- Intuitive user interface
- High robustness
- Expandability
- Failure forecasts for increased quality / downtime reduction
Prozesskennzahl v3.0 / Key features

- Monitoring state and forecast
- Update time ~30 seconds
- Alarm events via automated emails
- Error-Logging / avoiding crashes
User Interface

- Current machine status
- Visualization for up to 72 hours
- Main status
- Summarized Info
- Visualize sensor data
- Limits to trigger alarms and warnings
- Forecast analysis
Plug-In feature

- Add new machines without code changes
- Customized calculation and visualization per machine
- Code for plug-in and main application separated
Which sensor measurements indicate machine failure?
Process Monitoring Algorithms and Software

Basic Workflow

1. Preprocess Data
   - Choose Algorithm
   - Fit Model
   - Evaluate Model
   - Choose Model
   - Make Predictions
Process Monitoring Algorithms and Software
Pre-Processing

Sensor data and quality states are aggregated (per time stamp)
Process Monitoring Algorithms and Software - Train a prediction model

Basic Workflow

1. Choose Model
2. Choose Algorithm
   - Preprocess Data
   - Fit Model
   - Evaluate Model
   - Make Predictions
Process Monitoring Algorithms and Software—Train a prediction model

Possible Classification Methods

Statistics and Machine Learning

- Nearest Neighbor Classification
- Support Vector Machines
- Classification Trees
- Bayes Classification
- Discriminant Analysis

Neural Network
Process Monitoring Algorithms and Software - Train a prediction model

Basic Workflow

1. Preprocess Data
2. Choose Algorithm
3. Fit Model
4. Evaluate Model
5. Choose Model
6. Make Predictions
Process Monitoring Algorithms and Software – Train a prediction model

Fit model based on historic data

Training Data
e.g. 60% of historic data (3 months)

PredictionModel = fitctree(PROPERTY, STATE)
Process Monitoring Algorithms and Software - Train a prediction model

Basic Workflow

1. Preprocess Data
2. Choose Algorithm
3. Fit Model
4. Evaluate Model
5. Choose Model
6. Make Predictions
Process Monitoring Algorithms and Software – Train a prediction model

Validation Data, e.g. 40% of historic data (3 months)

<table>
<thead>
<tr>
<th>TIMESTAMP</th>
<th>PARAMETER</th>
<th>STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-07-14 00:49:12.0</td>
<td>160 160 160 160 1000</td>
<td>7 1000 9 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:50:12.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 10 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:51:13.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 10 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:52:12.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 10 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:53:12.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 11 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:54:12.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 12 33 32</td>
</tr>
<tr>
<td>2015-07-14 00:55:12.0</td>
<td>160 160 160 160 1000</td>
<td>8 1000 10 33 32</td>
</tr>
</tbody>
</table>

predictedState = PredictionModel(Parameter)

Misclassification rate 1 of 7: 14.28%
Process Monitoring Algorithms and Software –

Basic Workflow

1. Preprocess Data
2. Choose Algorithm
3. Fit Model
4. Evaluate Model
5. Choose Model
6. Make Predictions
Process Monitoring Algorithms and Software - Application

Predict current machine states during operation

Sensor Data (10-100 /plant)

Quality State

Prediction Model

Sensor data (now)

Train Prediction Model (historic data)

State is: ok

Predicted State (now)

update ~ 1min.

update ~ 60-90 min.
Process Monitoring Algorithms and Software - Application

State is: ok

Fehlerrate

14.85 %

Abgleichsraten

0 %
Thank you!

Questions?