Failure prediction and process monitoring using Machine Learning at MONDI Gronau

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05/2016

Plant

Mondi Gronau GmbH

Jöbkesweg 11
48599 Gronau, Deutschland

Local: ~ 850 employees
Global: ~ 25.000 employees

Mildenberger & 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

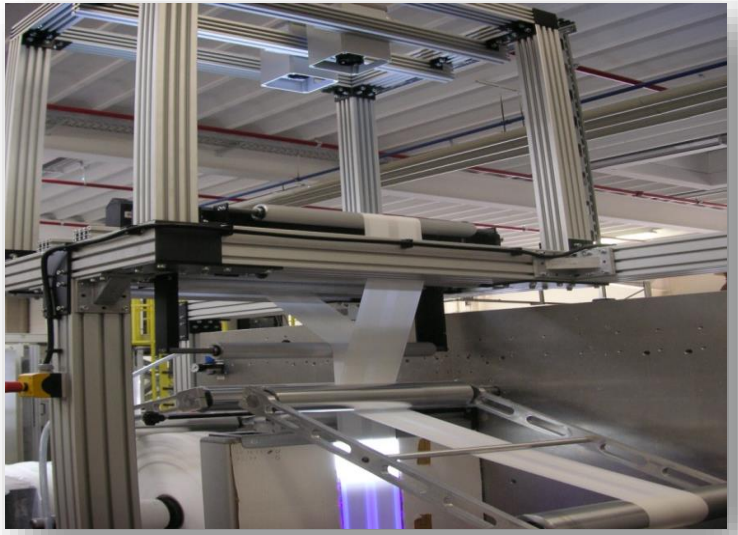
Benefits

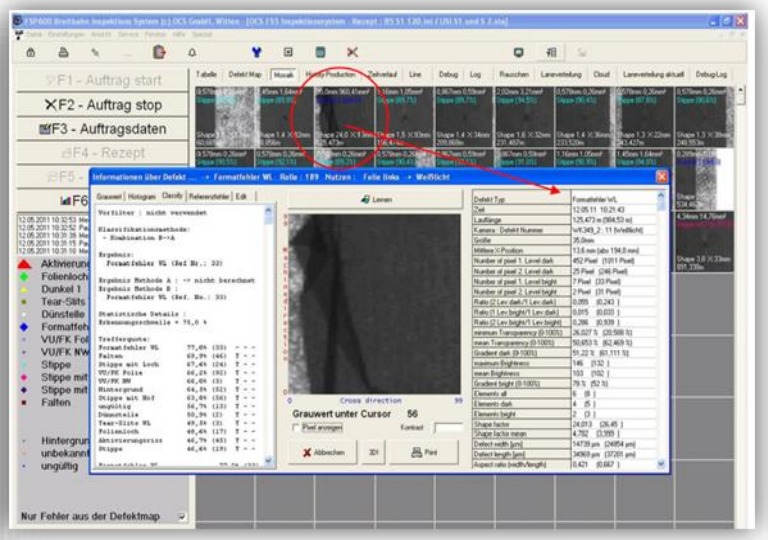
- Advanced Quality Monitoring
- Reduction of Waste Material
- Customer Satisfaction
- Yield Optimization

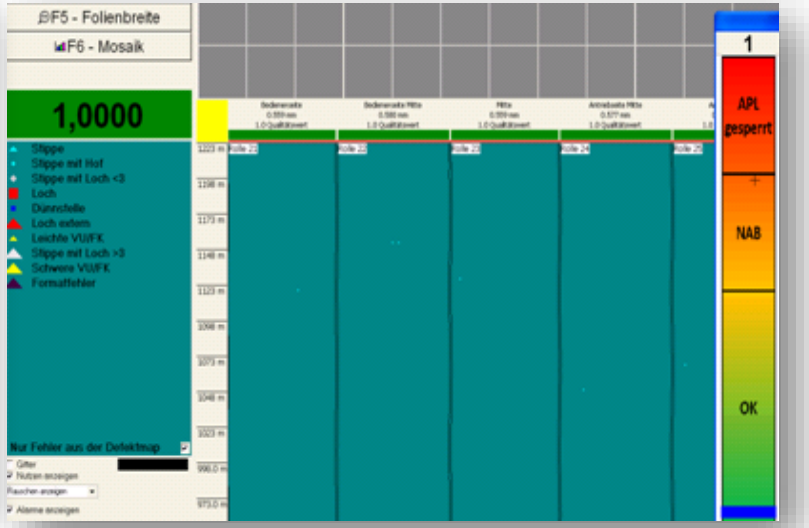
Monitoring Systems

Monitoring: In-Line

Integrated Monitoring System





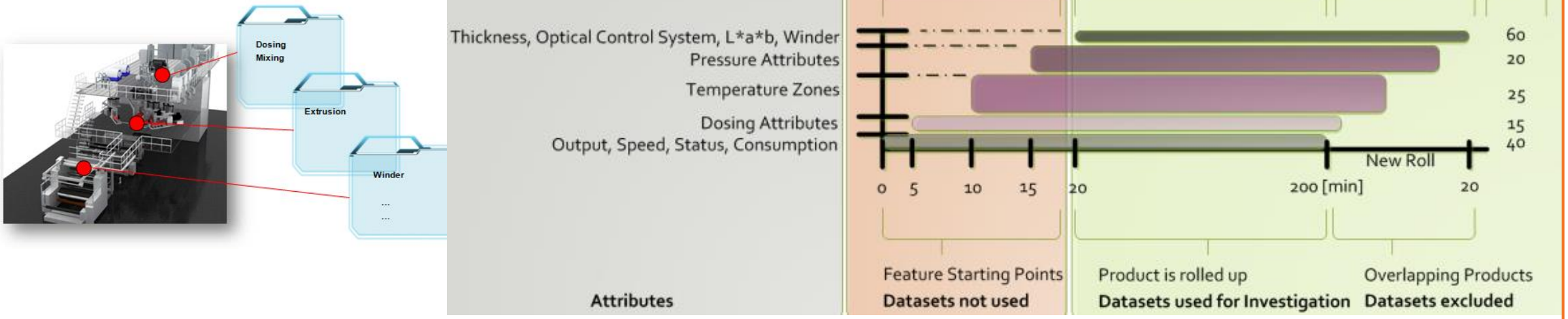


Optical Control System

- Laminated Film Surface Detection
- Traffic Light System
- Quality Index
- Addional Systems: Colour, Thickness

Monitoring: PLC Data

Data Acquisition



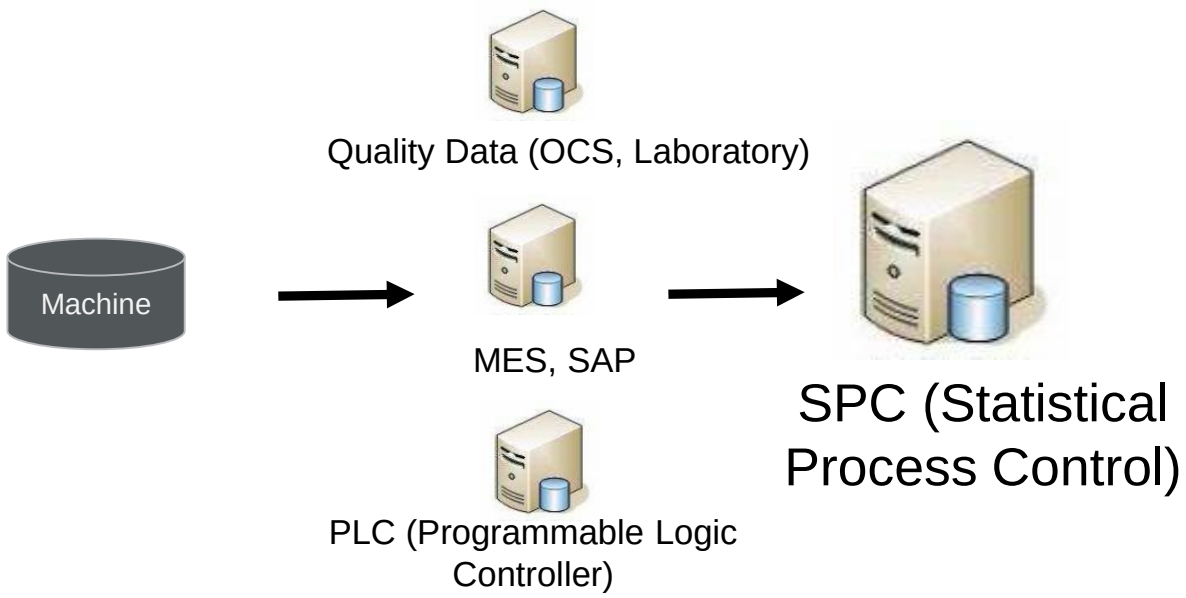
PLC

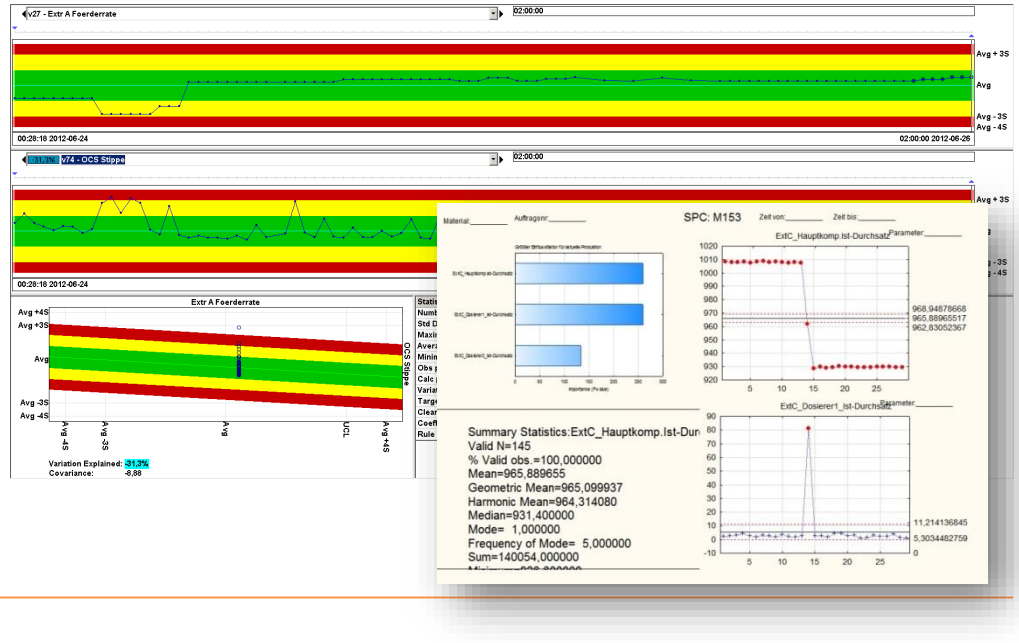
- Parameters/ Features (100 – 500)
- PLC (Programmable Logic Controller), Data Collector
- 4-5 PLC per machine for real-time acquisition

Data Processing

Processing

First Step in Visualization



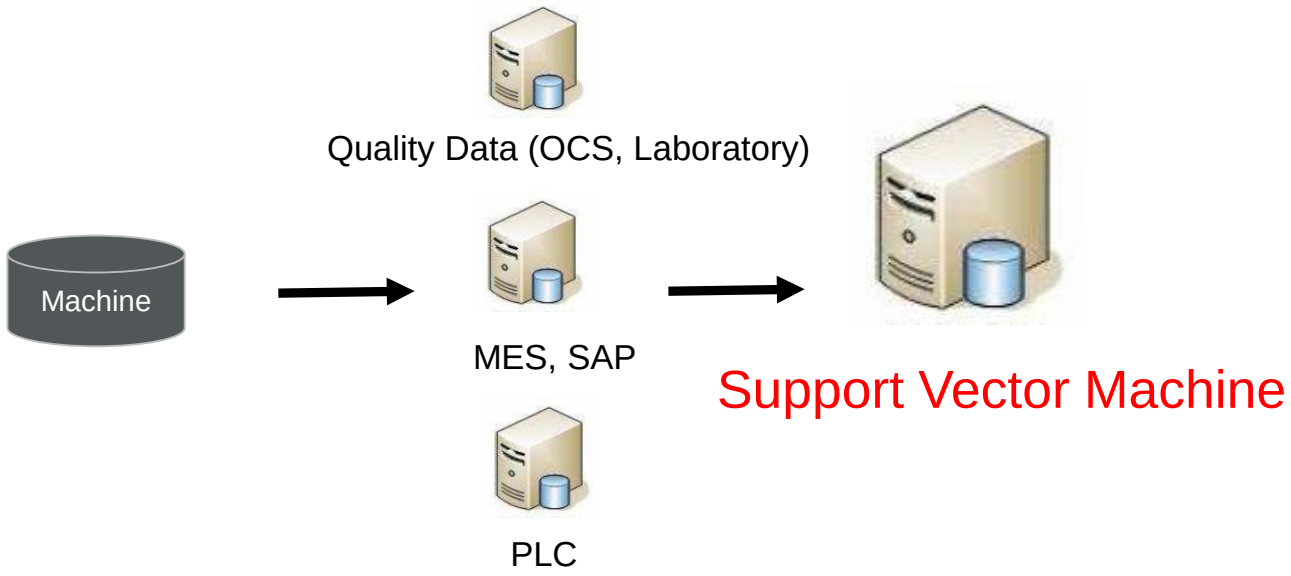


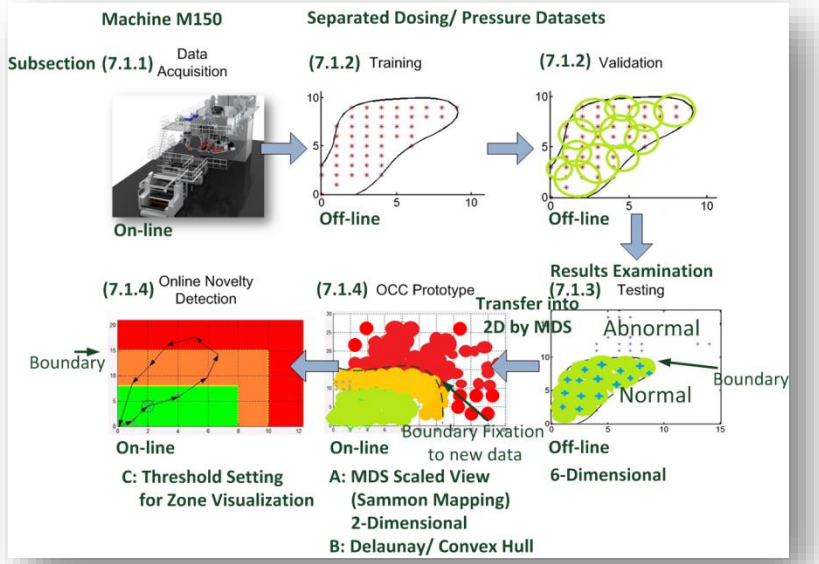
Acquisition Loop

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

Processing

Next Step in using Prediction Methods



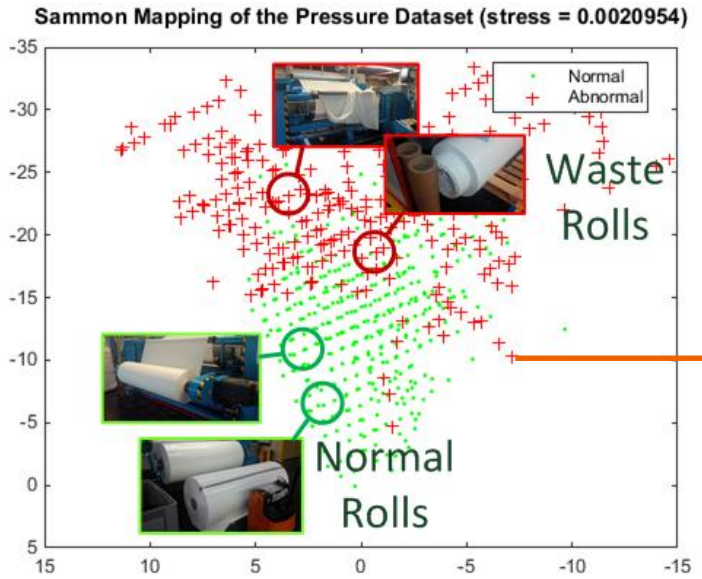


Acquisition Loop

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

Processing

Next Step in understandable Visualization



Up to 200 parameters in one point [temperature, pressure, speed,…]

Acquired per minute

Stored on an Oracle database

Processed for visualization in lower dimensions

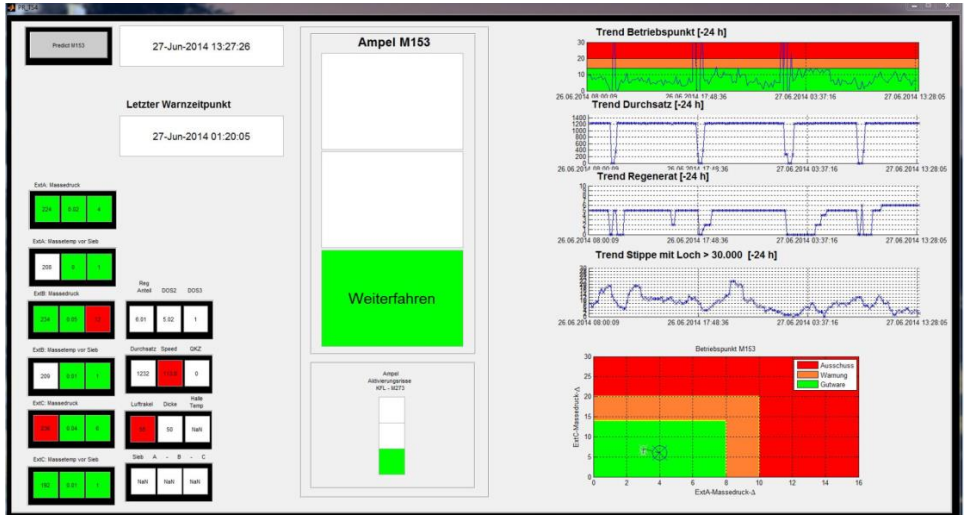
Visualization

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

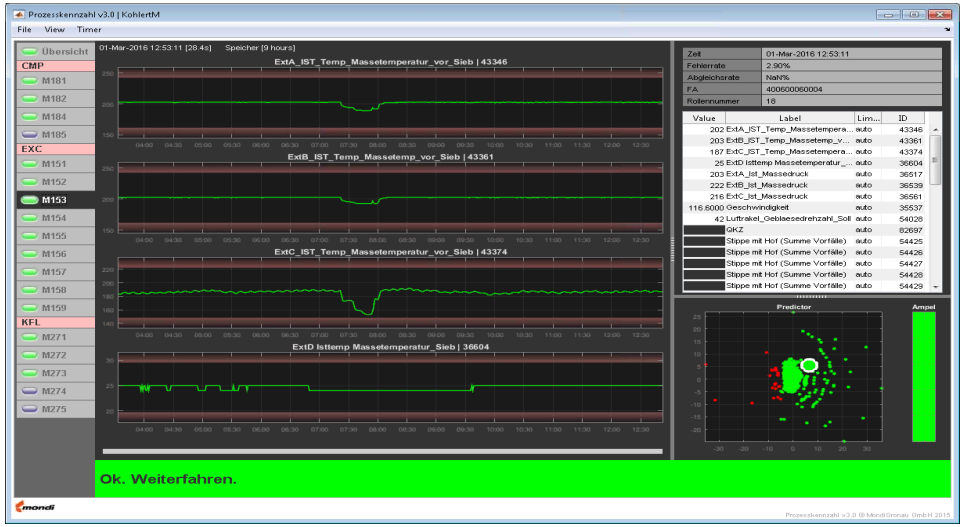
Processing

Next Step in Software Development

Version 1.0 (internal)



Version 3.0 (Mathworks)



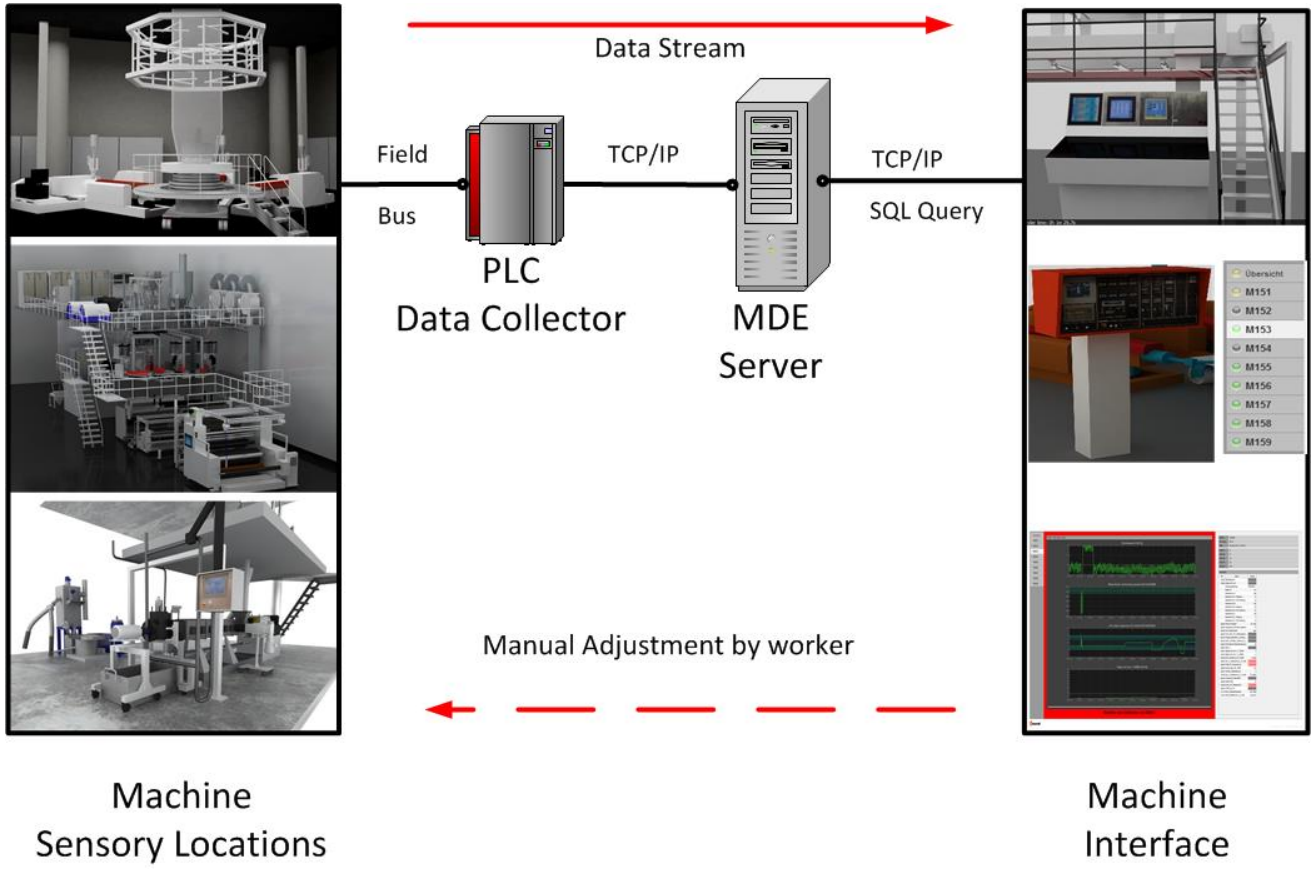
Acquisition Loop

- 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

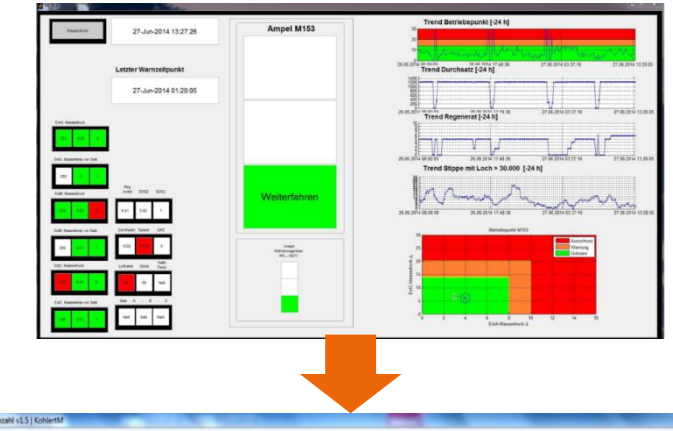
Processing Loop



- Open Processing Loop
- Recommendation System

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

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- Up to 40 machines with up to 500 sensors
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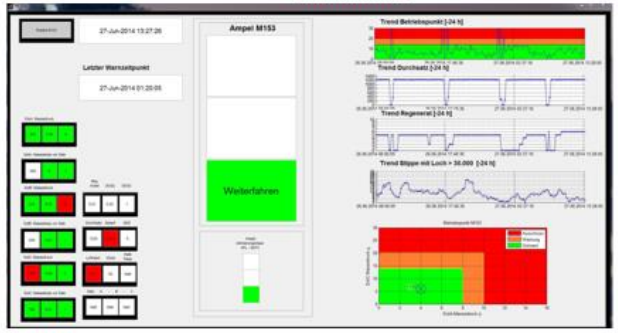
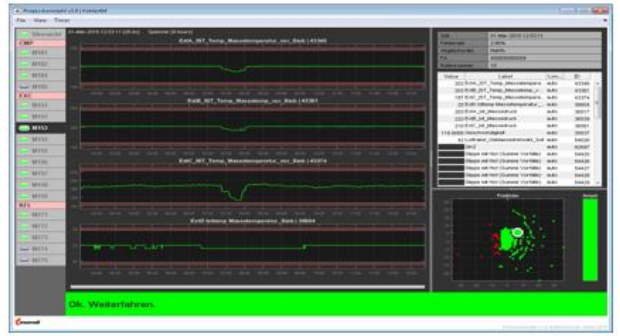
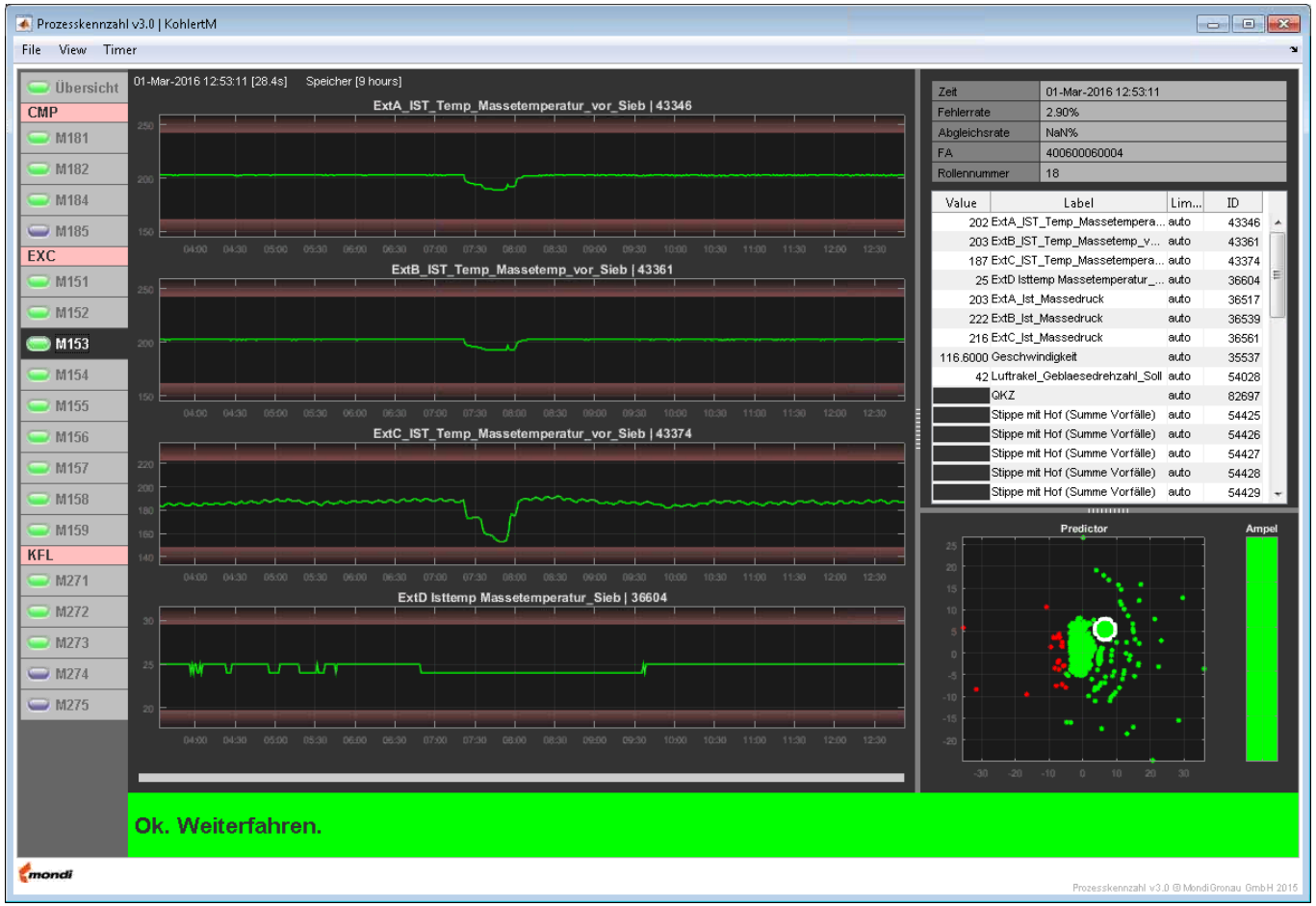


Version 3.0 (Mathworks)



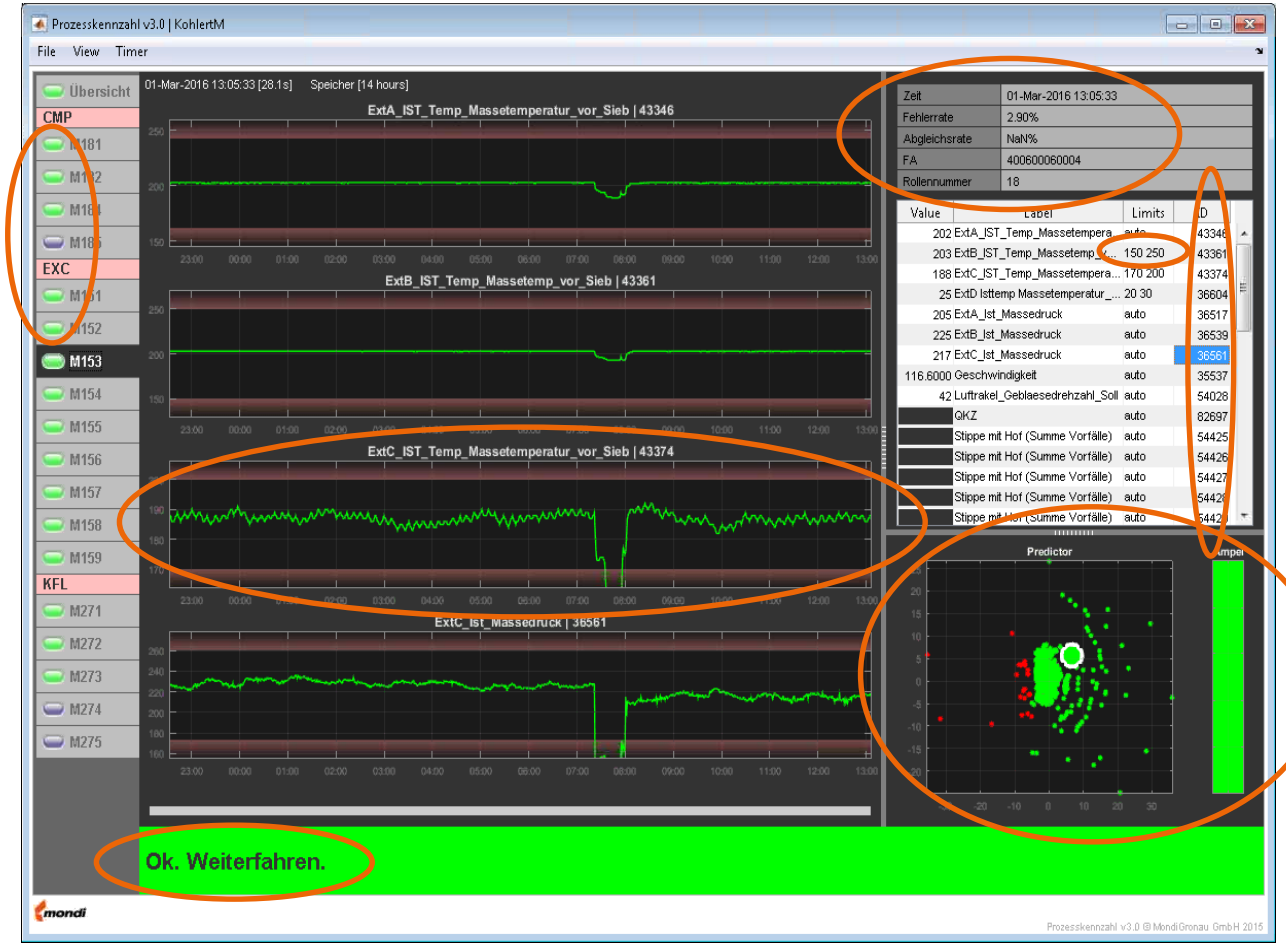
Prozesskennzahl v3.0 / Key features



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

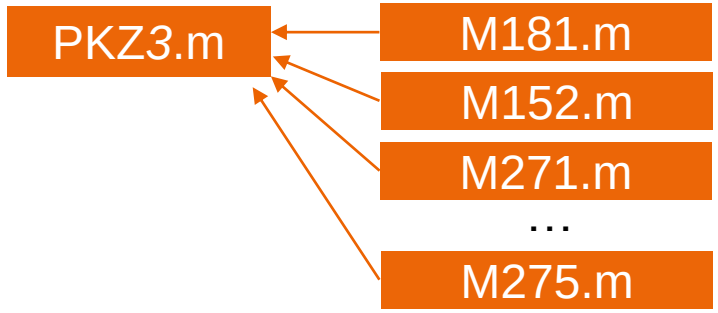
User Interface

- Current machine status
- Visualization for up to 72 hours
- Main status

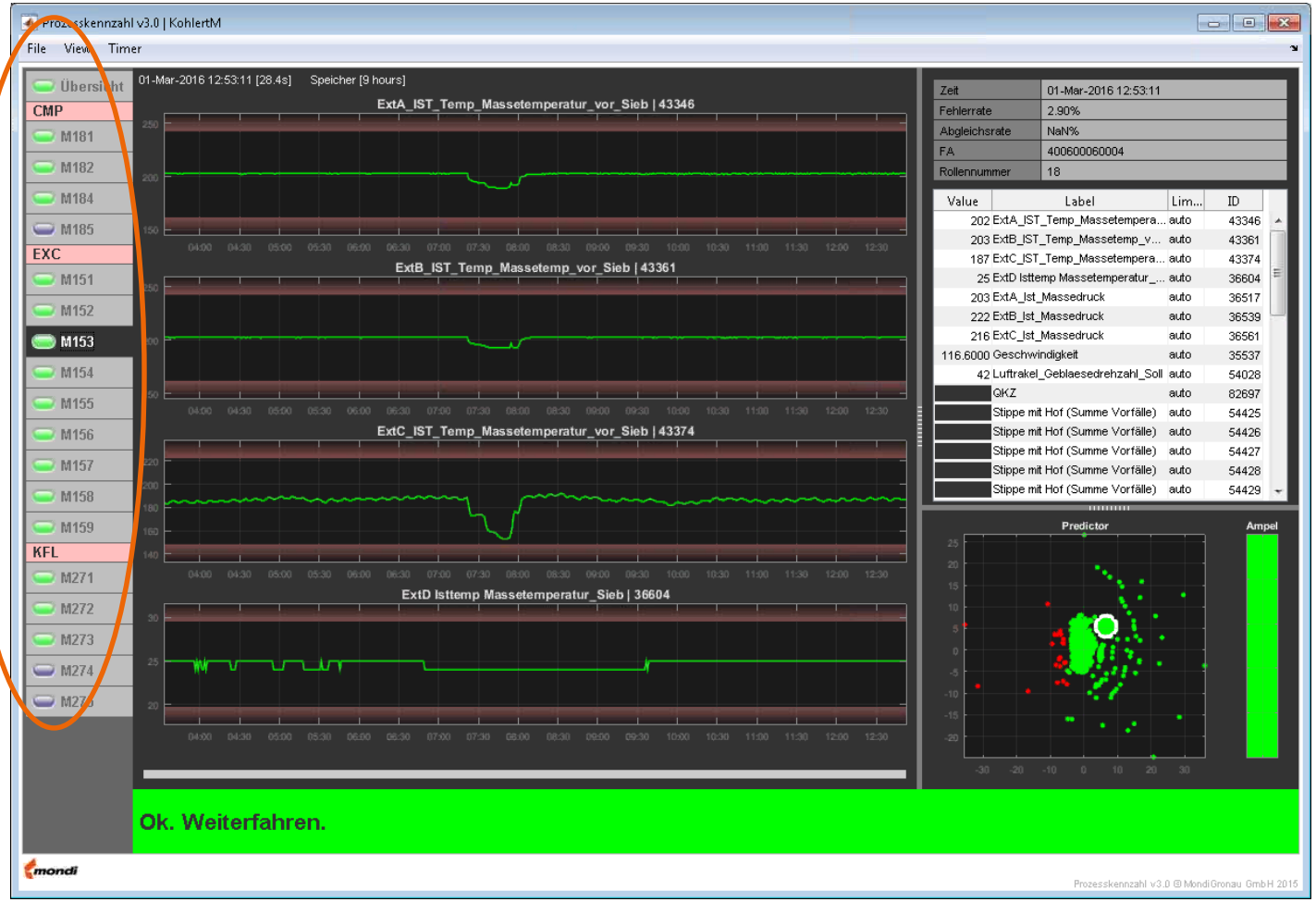


- Summarized Info
- Visualize sensor data
- Limits to trigger alarms and warnings
- Forecast analysis

Plug-In feature



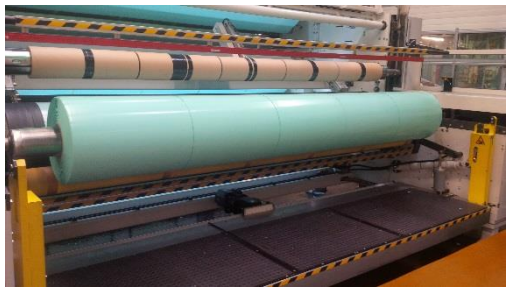
- Add new machines without code changes
- Customized calculation and visualization per machine
- Code for plug-in and main application separated



Next:

Algorithms
Software

Process Monitoring Algorithms and Software



Sensor Data
(10-100 /plant)

update ~ 1min.

PLC

Quality State

update ~ 60-90 min.

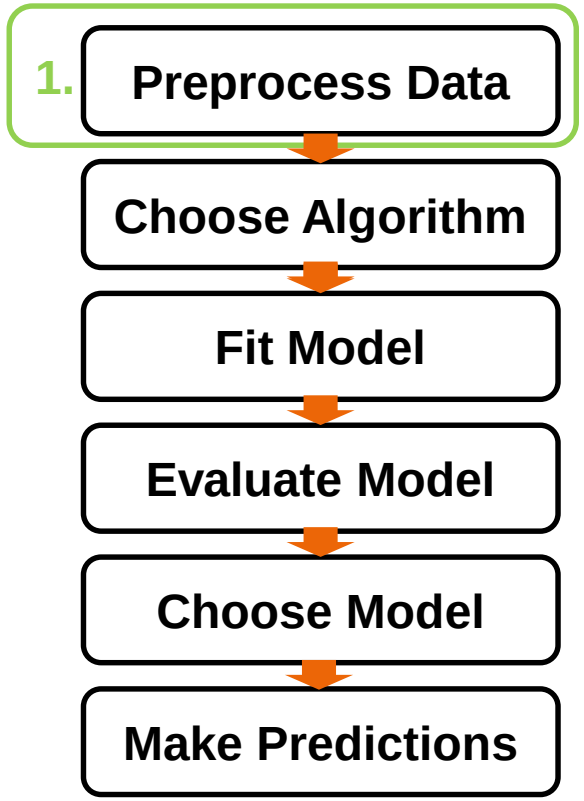
MES, SAP

Quality Data (OCS, Laboratory)

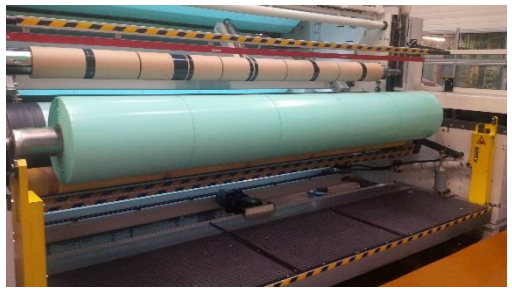
Which sensor measurements indicate machine failure?

Process Monitoring Algorithms and Software

Basic Workflow



Process Monitoring Algorithms and Software Pre-Processing



update ~ 1min.

update ~ 60 min.

Sensor Data (10-100 /plant)

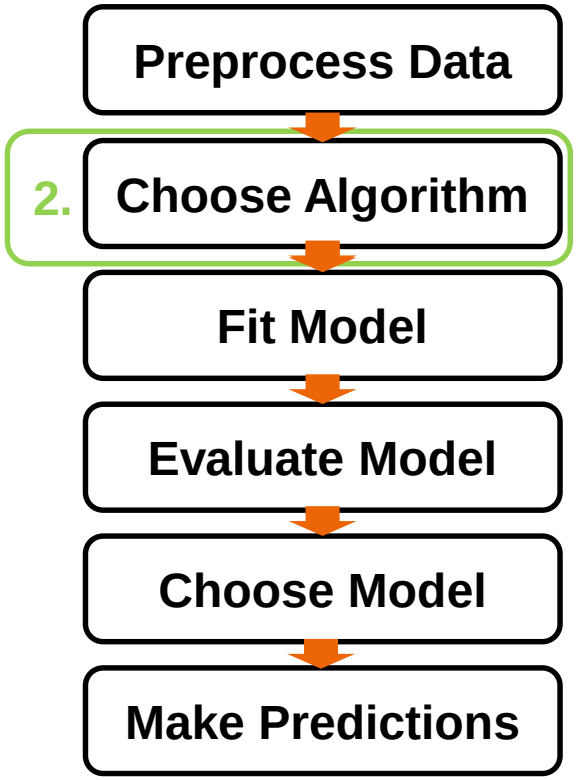
Quality State

1 TIMESTAMP	2 PARAMETER										3 STATE
'2015-07-14 00:49:12.0'	160	160	160	160	1000	7	1000	9	33	32	1
'2015-07-14 00:50:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:51:13.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:52:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:53:12.0'	160	160	160	160	1000	8	1000	11	33	32	2
'2015-07-14 00:54:12.0'	160	160	160	160	1000	8	1000	12	33	32	2
'2015-07-14 00:55:12.0'	160	160	160	160	1000	8	1000	10	33	32	2

Sensor data and quality states are aggregated (per time stamp)

Process Monitoring Algorithms and Software - Train a prediction model

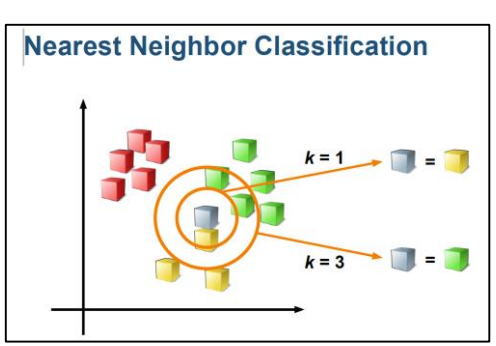
Basic Workflow

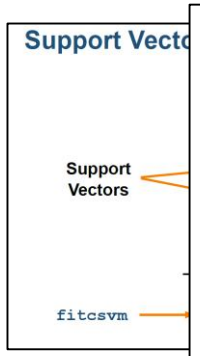


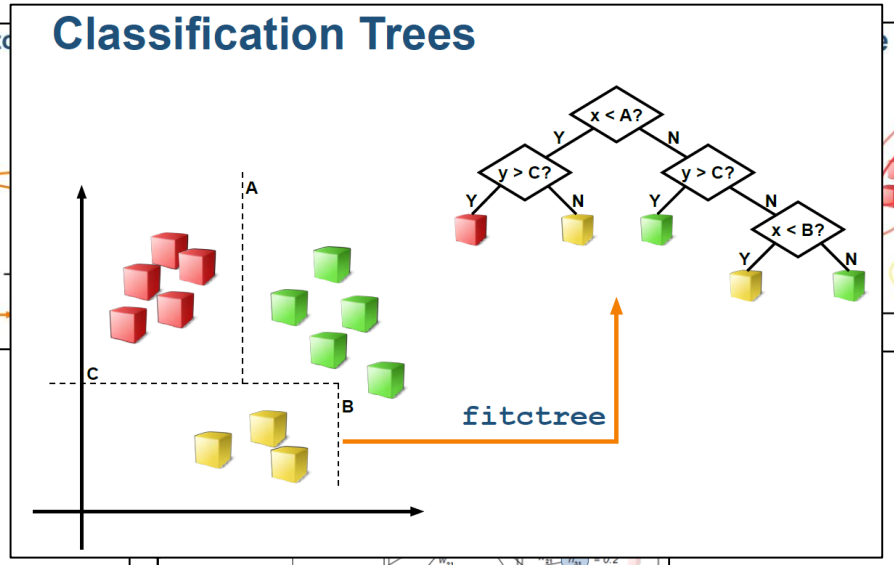
Process Monitoring Algorithms and Software– Train a prediction model

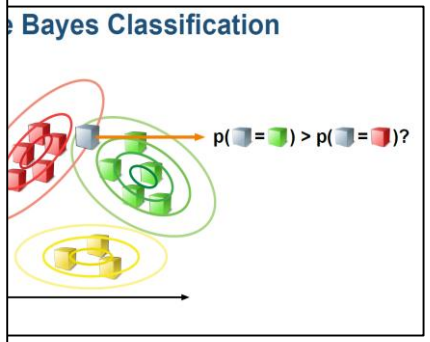
Possible Classification Methods

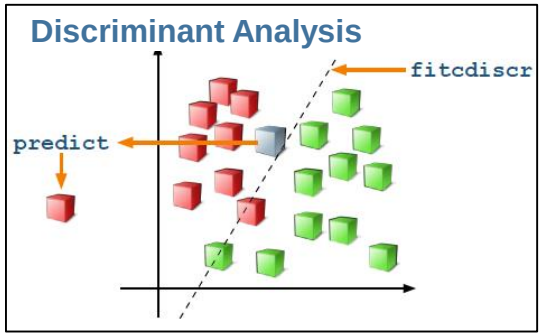
Statistics and Machine Learning



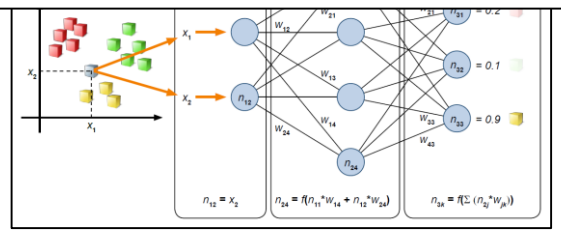






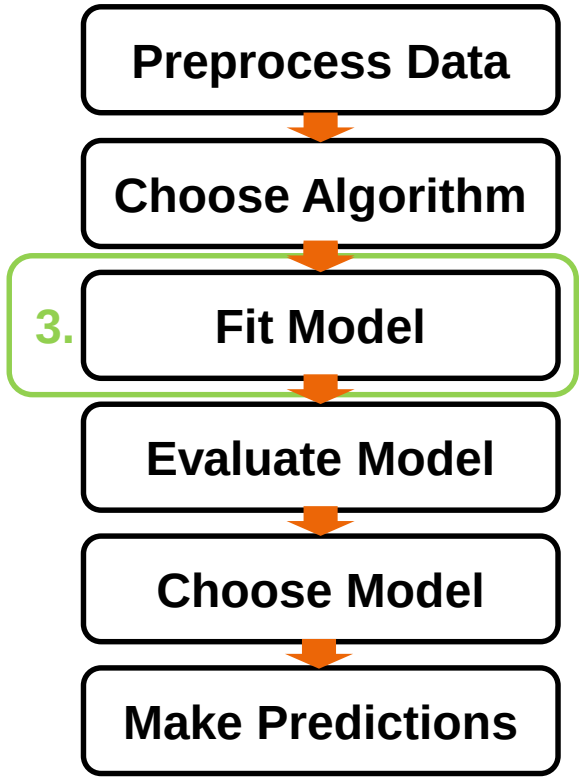


Neural Network



Process Monitoring Algorithms and Software - Train a prediction model

Basic Workflow



Process Monitoring Algorithms and Software– Train a prediction model

Fit model based on historic data

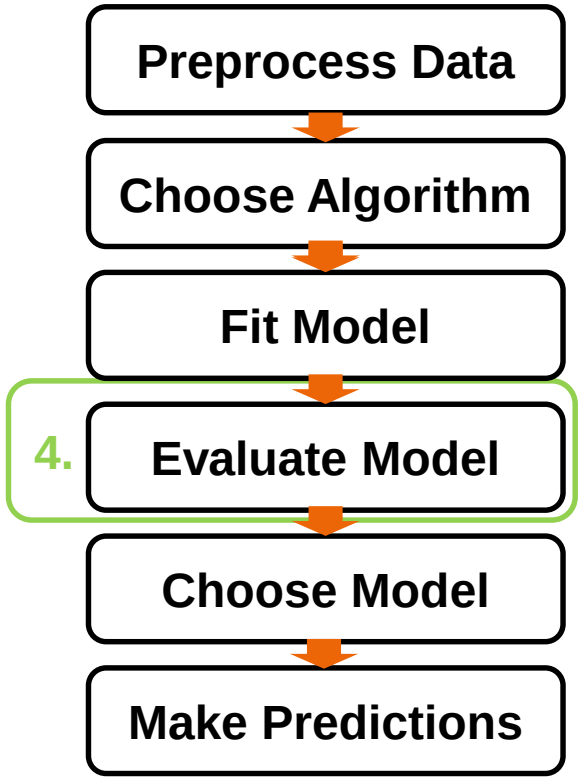
```
PredictionModel = fitctree(PARAMETER, STATE)
```

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

1 TIMESTAMP	2 PARAMETER										3 STATE
'2015-07-14 00:49:12.0'	160	160	160	160	1000	7	1000	9	33	32	1
'2015-07-14 00:50:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:51:13.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:52:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:53:12.0'	160	160	160	160	1000	8	1000	11	33	32	2
'2015-07-14 00:54:12.0'	160	160	160	160	1000	8	1000	12	33	32	2
'2015-07-14 00:55:12.0'	160	160	160	160	1000	8	1000	10	33	32	2

Process Monitoring Algorithms and Software - Train a prediction model

Basic Workflow



Process Monitoring Algorithms and Software – Train a prediction model

predictedState = PredictionModel(Parameter)

PredictionModel

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

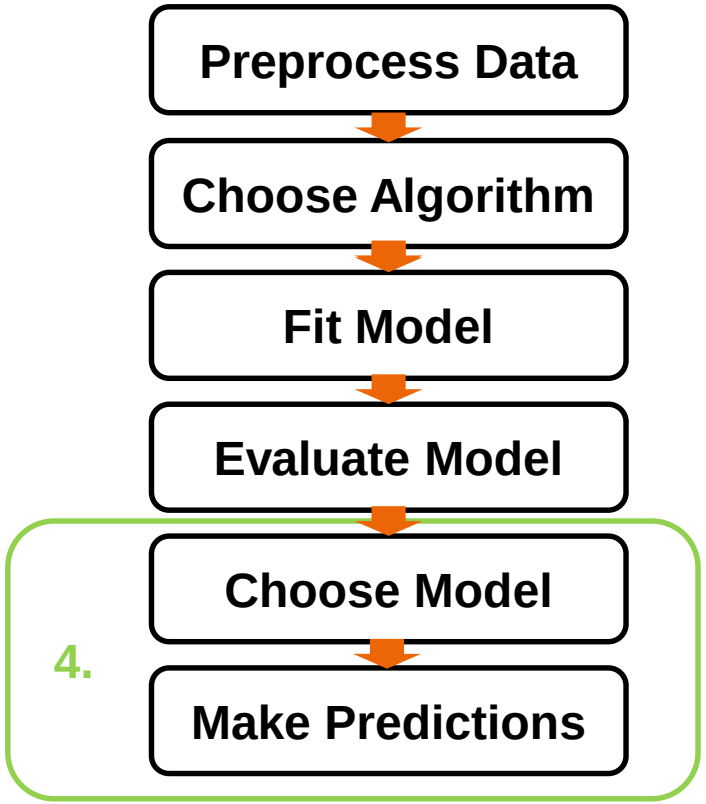
1 TIMESTAMP	2 PARAMETER										3 STATE
'2015-07-14 00:49:12.0'	160	160	160	160	1000	7	1000	9	33	32	1
'2015-07-14 00:50:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:51:13.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:52:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:53:12.0'	160	160	160	160	1000	8	1000	11	33	32	2
'2015-07-14 00:54:12.0'	160	160	160	160	1000	8	1000	12	33	32	2
'2015-07-14 00:55:12.0'	160	160	160	160	1000	8	1000	10	33	32	2

predictedState
1
1
1
1
2
2
1

Misclassification rate 1 of 7: 14.28 %

Process Monitoring Algorithms and Software –

Basic Workflow



Process Monitoring Algorithms and Software - Application

Predict current machine states during operation

update ~ 1min.

update ~ 60-90 min.

Sensor Data (10-100 /plant)

Quality State

1 TIMESTAMP	2 PARAMETER										3 STATE
'2015-07-14 00:49:12.0'	160	160	160	160	1000	7	1000	9	33	32	1
'2015-07-14 00:50:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:51:13.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:52:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
'2015-07-14 00:53:12.0'	160	160	160	160	1000	8	1000	11	33	32	2
'2015-07-14 00:54:12.0'	160	160	160	160	1000	8	1000	12	33	32	2
'2015-07-14 00:55:12.0'	160	160	160	160	1000	8	1000	10	33	32	2

State is: **ok**

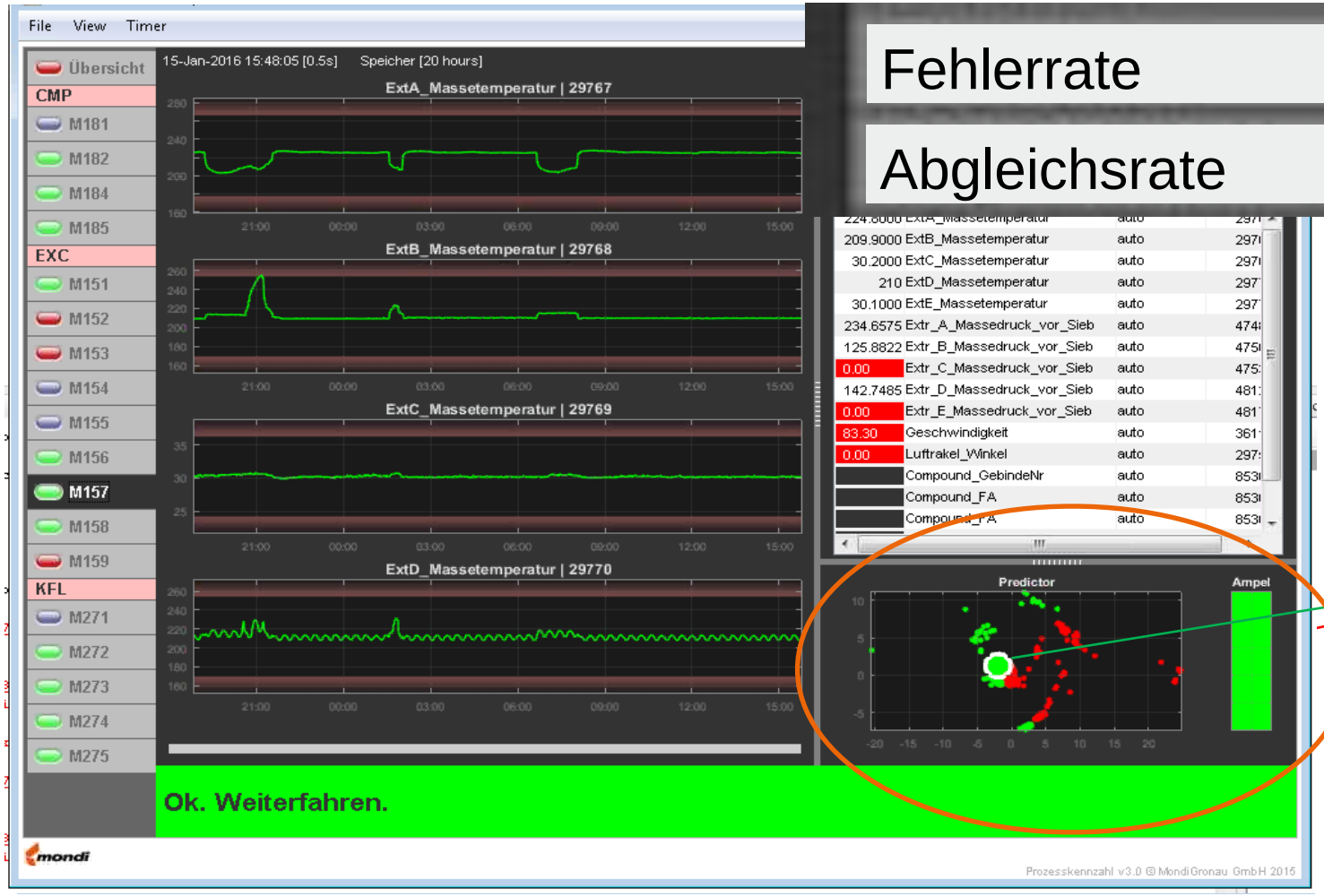
Sensor data (now)

Prediction Model

Train Prediction Model (historic data)

Predicted State (now)

Process Monitoring Algorithms and Software - Application



Fehlerrate	14.85 %
Abgleichsrate	0 %

State is: ok

Thank you!

Questions?