Data driven Process Optimization in the Beverage Industry based on Machine Learning

Consortium:

Supported by

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages
DLR Projektträger

Project Overview and Insights

ARIC Brown Bag Session, 22.02.2022

Institut für Produktionssysteme (IPS)

- Gegründet 2012
- Forschung im Bereich Industrial Engineering und Gestaltung von Produktionssystemen seit den 1980er Jahren durch die Vorgängerlehrstühle LFV und APS
- Aktuell ca. 40 wissenschaftliche und techn. Mitarbeiter
- Enge Kooperation mit dem RIF Institut für Forschung und Transfer sowie der University of Technology Sydney UTS

IPS Institut für Produktionssysteme

Prof. Dr.-Ing. Jochen Deuse

Dr.-Ing. Ralph Richter

RIF Institut für Forschung und Transfer e.V.

- Gegründet 1990 als An-Institut der TU Dortmund
- Gründungsmitglied der Johannes Rau Forschungsgesellschaft und ZUSE Gemeinschaft
- Ca. 130 wissenschaftliche und technische Mitarbeiter
- Enge Kooperation der Abteilung Produktionssysteme mit dem IPS

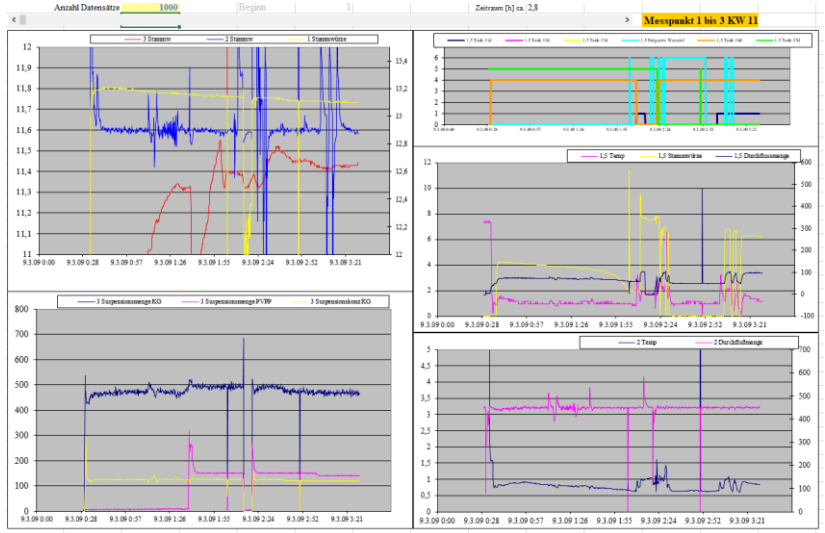
RIF Institut für Forschung und Transfer

Project scope of DaPro

Limits of Lean and descriptive statistics demand for new approaches for data-driven improvement

Problem

- Increasing social and economic factors lead to the need for using available resources as efficiently as possible
- Problem: Biochemical processes with complex combination of different influencing variables
- Classical improvement tools (Lean/Six Sigma) limit simultaneous analysis to a maximum of 2 to 3 factors



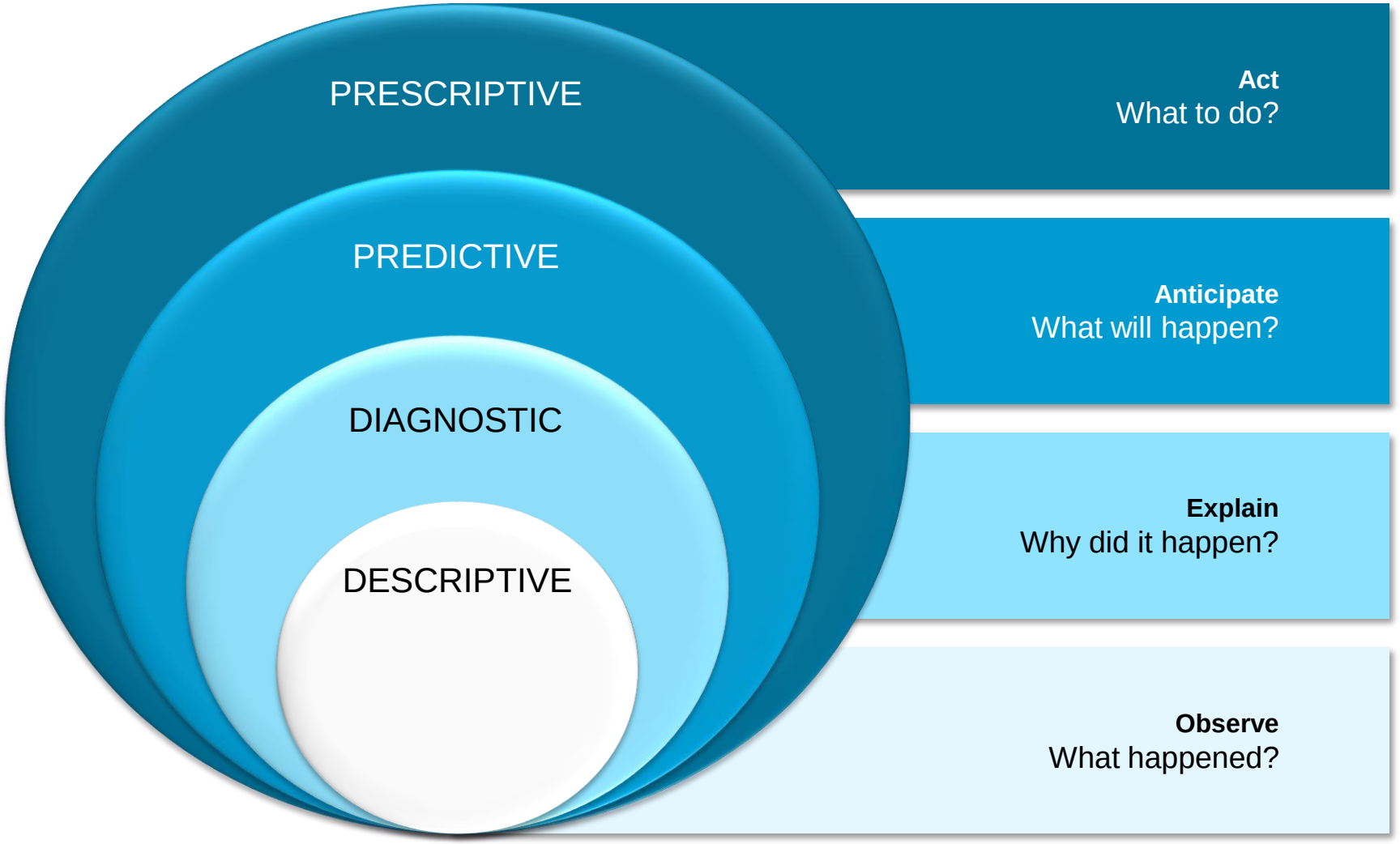
Approach

- Many breweries collect huge data on processing and results in separate systems, but don't use their potential
- Machine Learning (ML) help analyzing large amounts of data with multivariate influencing variables, but is still in its earliest stages in the beverage industry

DIY tools and guidelines for breweries to use of ML for data-driven process optimization

Project scope of DaPro

What kind of use cases are of interest?



[RapidMiner]

Project scope of DaPro

Interview Study on ML Use Cases in Beverage Industry

Descriptive: What happend?

- Inbound quality control
- Laboratory reports, quality inspection
- Energy reporting and controlling
- Filling reports
- Logistics reports
- Order reports: recipe and equipment parameters
- Numerous other reports
- **Analysis of the consumption of raw materials, energy and water**
- **Comparability between tanks**
- **…**

Diagnostic: Why did it happen?

- Laboratory: Root cause analyses of taste variations
- Root cause analyses of specification limits violations
- Analysis of the duration of the milling process and correlation with malt quantity
- Analysis of defects causes
- **Fast and direct identification of fault causes**
- **Customer satisfaction**
- **Causes of gushing**
- **…**

Predictive: What will happen?

- Sales forecasting, e.g. on the basis of weather data
- Predictive maintenance
- **Line balancing in filling: faster than simulation for complex problems**
- **Empties return forecasting**
- **Standing and throughput times for trucks**
- **Proactive supply chain control and buffer management**
- **Avoiding peak loads**
- **Predicting lautering time**
- **Predicting malt yield**
- **Predicting filter througput**

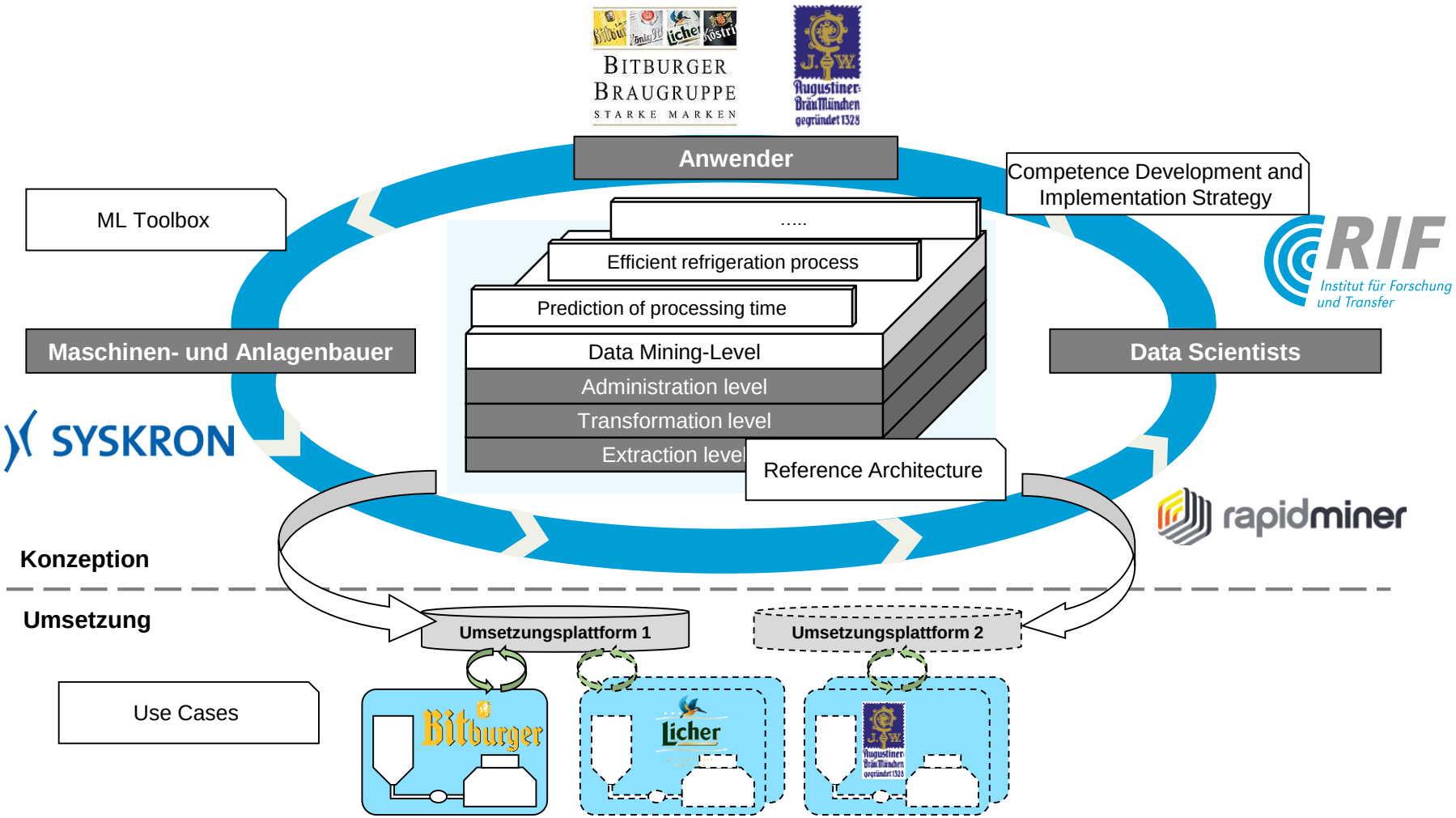
Prescriptive: How do I react?

- Fuzzy control of filtration processes
- Adaptive control of fermentation processes
- **Automated and throughput optimised control of the filtration process**
- **Use of predicted parameters for proactive process control (e.g. automatic control in the lauter tun)**
- **…**

[RIF/DaPro 2020]

Overview of Project Outcomes

Fields of Actions



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Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag
DLR Deutsches Zentrum für Luft- und Raumfahrt

Overview of Project Outcomes

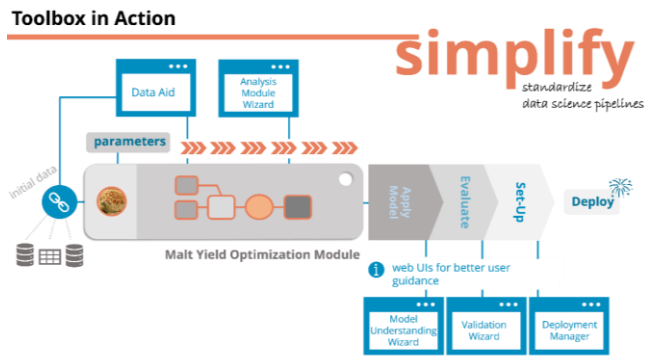
Tools and Methods for applying Machine Learning in Beverage Industry

…

Evaluation Assistant

Data Schema Operator

ML Toolbox



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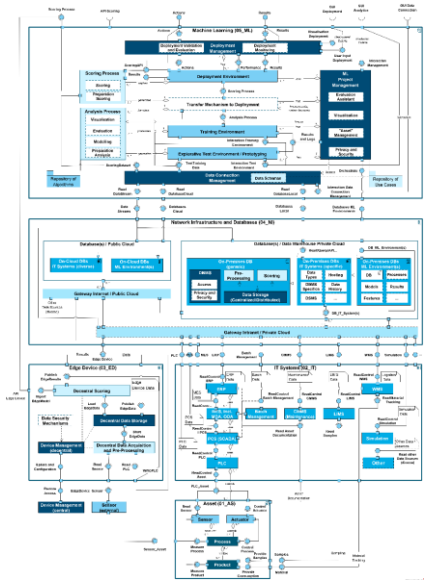
Machine Learning Layer

Network Infrastructure and Databases

Reference Architecture



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Anomaly Detection

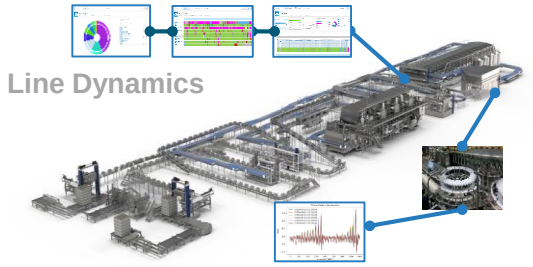
Malt Yield Prediction

Use Cases

Filtration

Malt Yield

Energy Consumption



Line Dynamics

Predictive Maintenance

Competence Development and Implementation Strategy

Overview of Project Outcomes

Use Cases

Optimierung der Malzausbeute

Vorhersage des Alpha-Gehalts des Hopfens

Analyse mikrobiologischer Kontamination

Prognose des LKW-Aufkommens

Schrotmühle

Lagertank

Hopfen

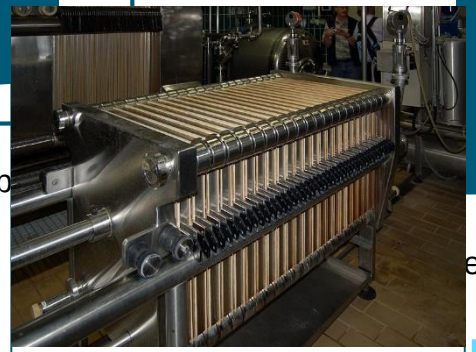
Maischeb

epfanne

Whi

Filtration

Prognose des Kältebedarfs



Prognose der Filterstandzeit

Predictive Maintenance

Analyse und Prognose füllerrelevanter Störungen

Energie- und Medienversorgung / Kältetechnik

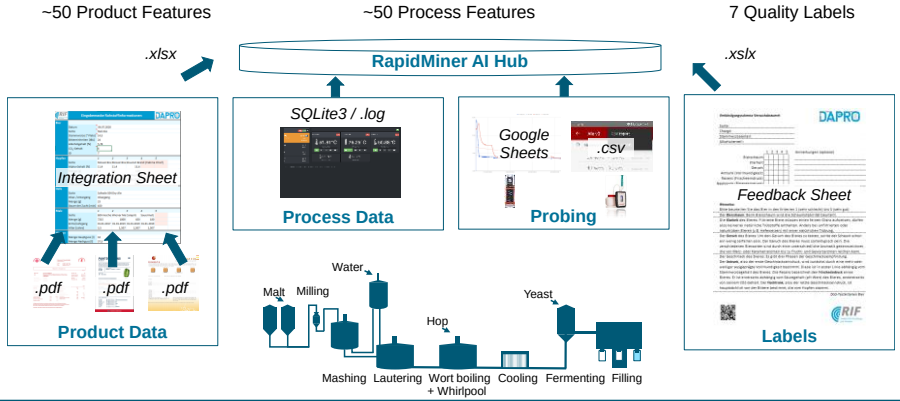
Overview of Project Outcomes

Use Cases

Optimierung der Malzausbeute

Schrotmühle

New Use Case: Recipe Optimization at Cyber-Physical Brewing Lab (RIF)



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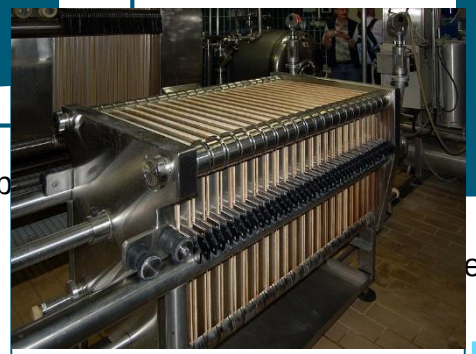


Prognose der Filterstandzeit

Predictive Maintenance

Analyse und Prognose füllerrelevanter Störungen

Energie- und Medienversorgung / Kältetechnik

Case Study: Prediction of Malt Yield

Overview

Goals

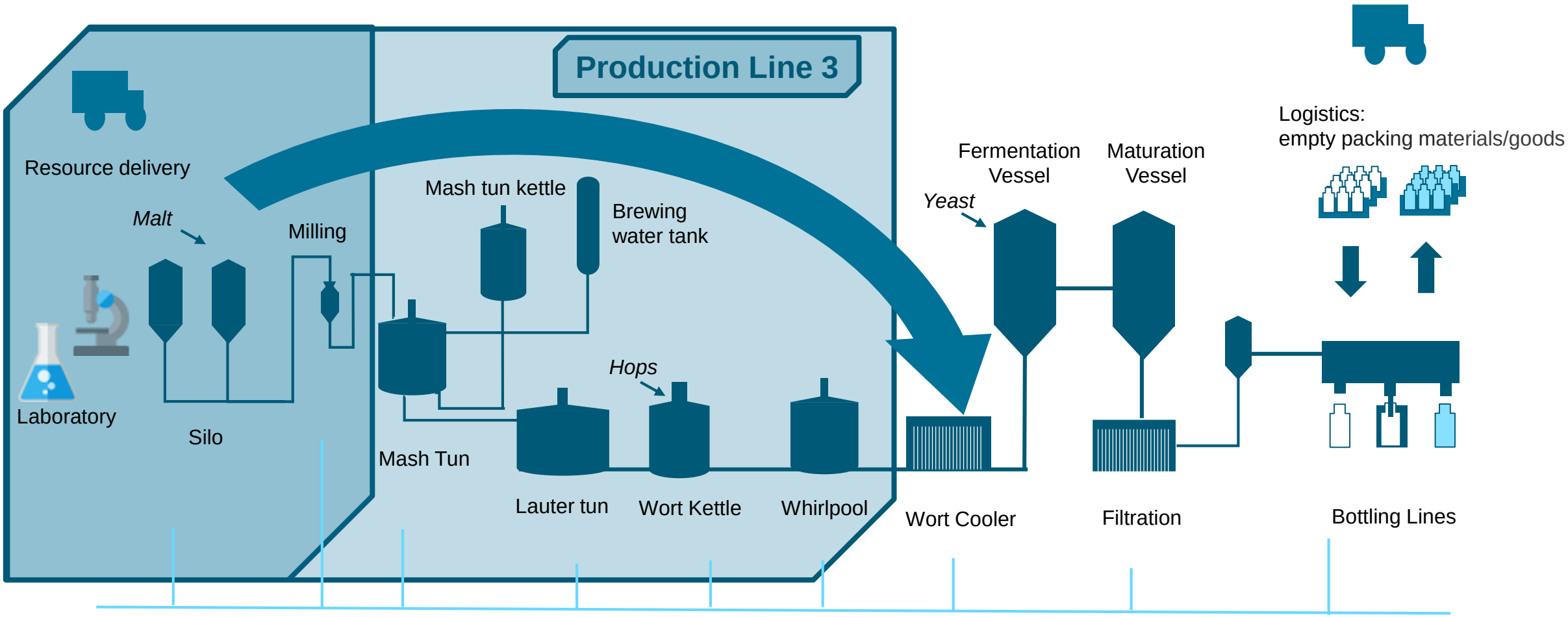
- More efficient and sustainable usage of malt in the brewery
- Target KPI (label): Malt Yield [%]
- Result: Prediction accuracy/RMSE: 0.88 ± 0.7 % error
- Benefits:
  - Prediction suitable for outlier detection.
  - Result available before production starts
- Challenges:
  - Silo Mapping (Resource deliveries to brew batches)

Data

- Data timeframe 06.10.2019 – 02.02.2021
- Process data: Production Line 3 (SCADA)
- Beer style: Pilsner Lager
- Malt batches:
  Quantities and Malt Quality parameters (LIMS)
- Silo levels

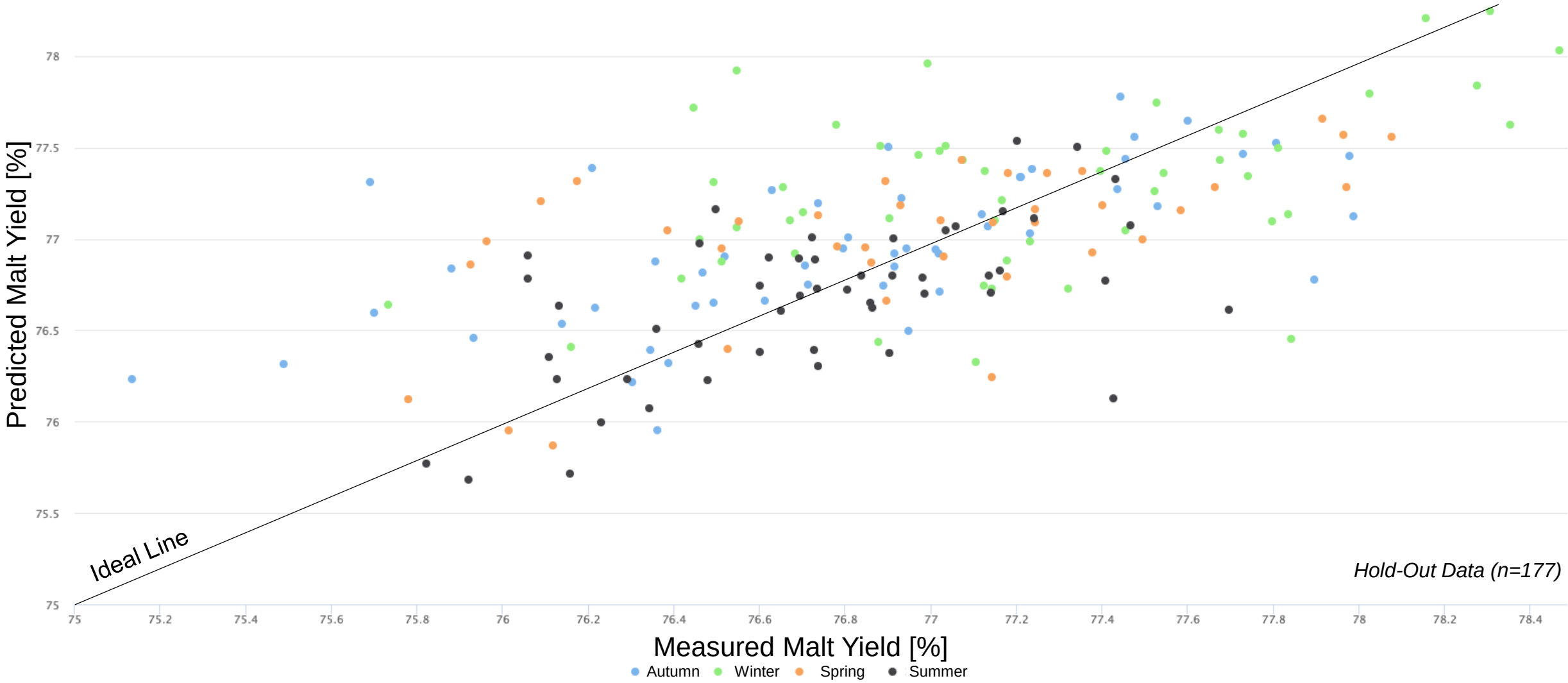
Case Study: Prediction of Malt Yield

Overview



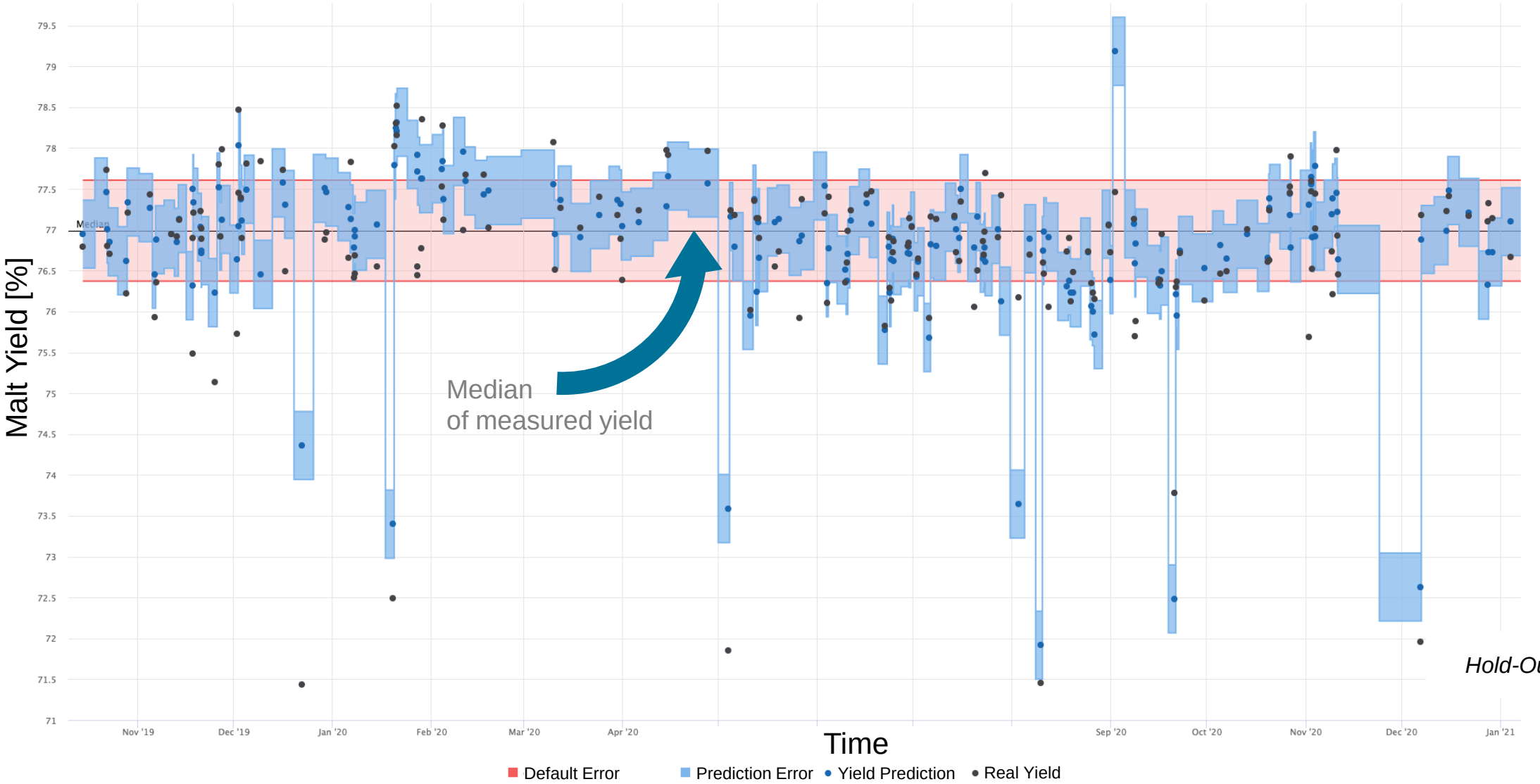
Case Study: Prediction of Malt Yield

Results: Overview of real vs. predicted malt yield



Case Study: Prediction of Malt Yield

Time-resolved yield predictions compared to deviation of measurement data



Hold-Out Data (n=177)

Case Study: Prediction of Malt Yield

Deployment

Data Flow

Historical Data

Sensors
SCADA
LIMS
...

Test and Training Environment

Join Data

Feature

Train & Evaluate Model

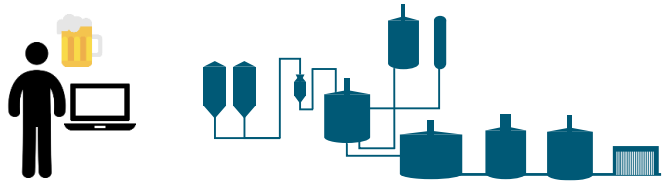
Real-Time Data

Sensors
SCADA
LIMS
...

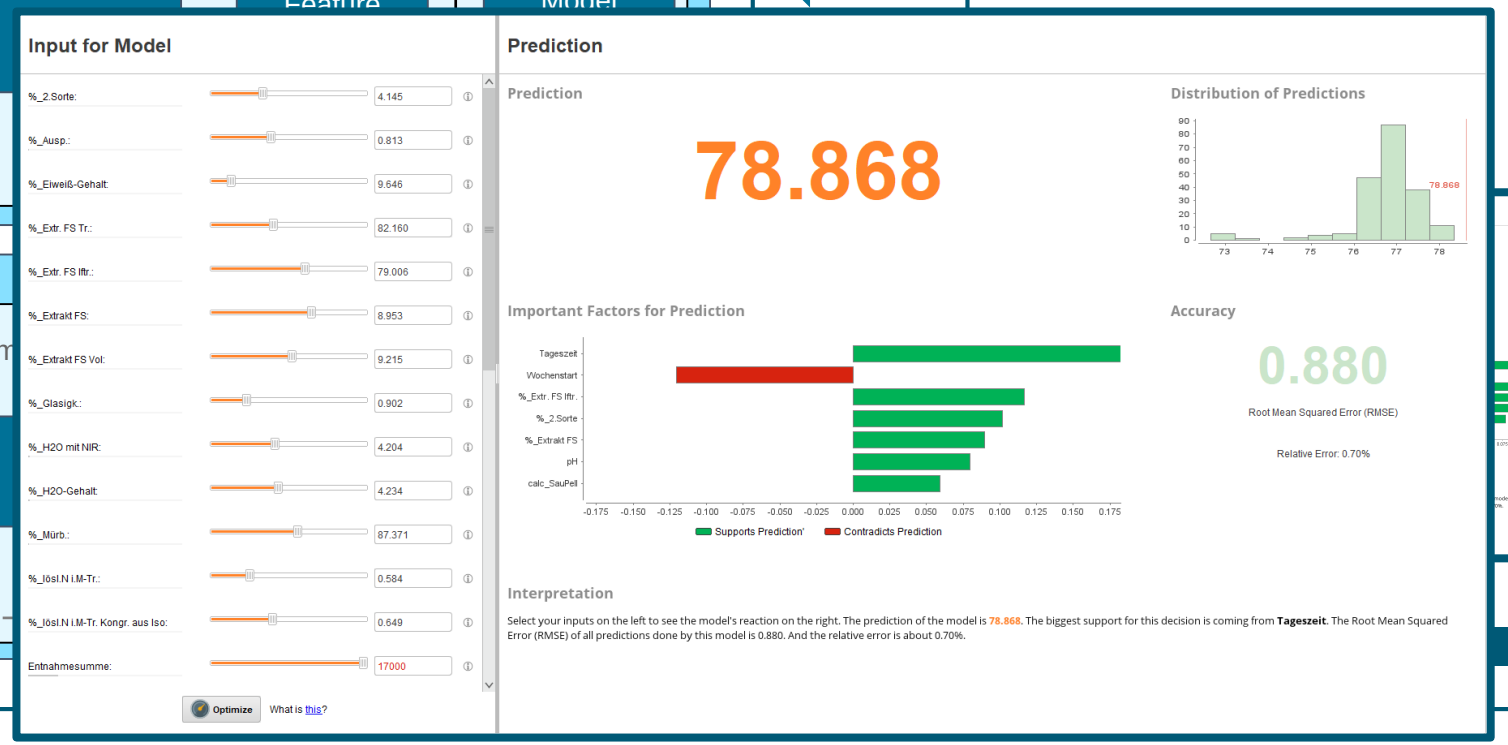
Deployment Environm

Join Data

Department

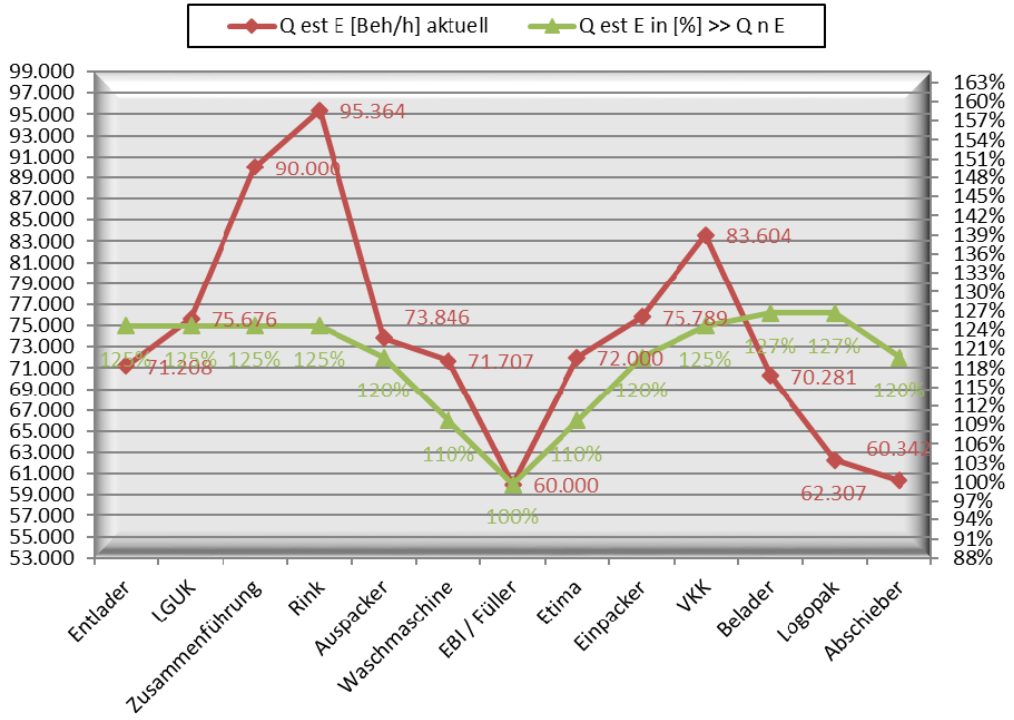


Brewhouse



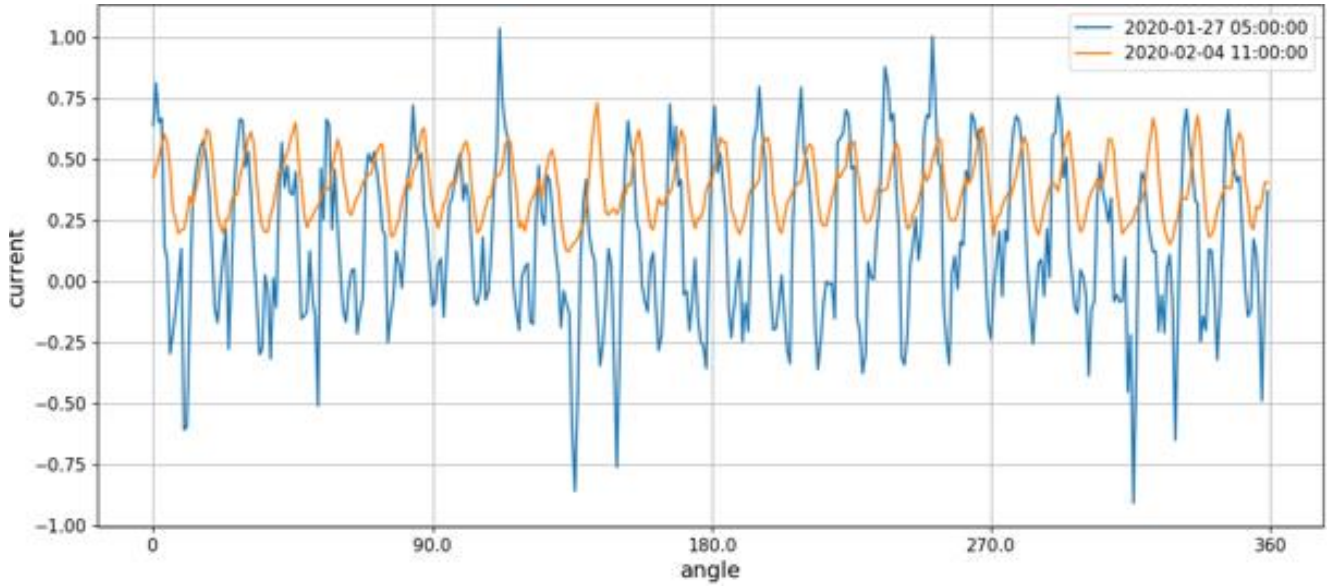
Situation in filling lines

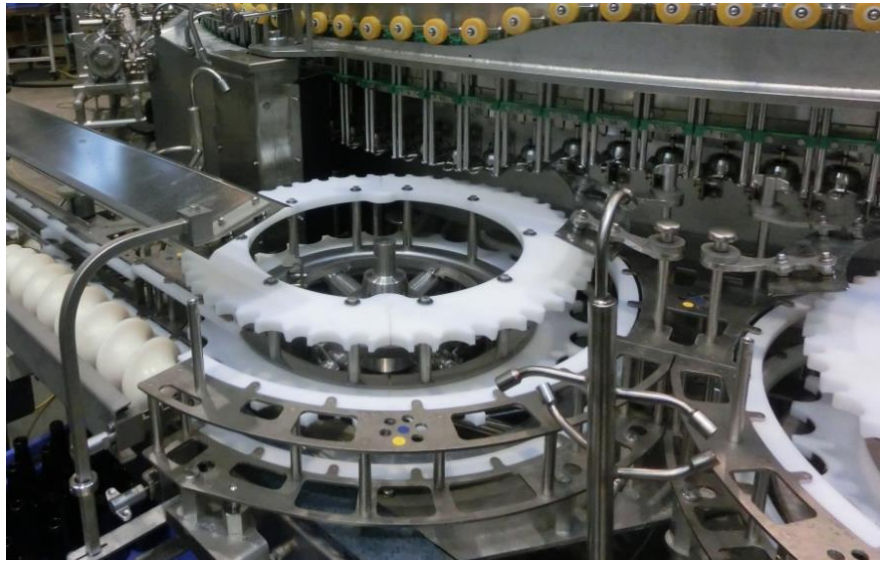
- Limited space, almost no stocks
- Time critical part of production – the filling department
- The filling machine is the bottleneck
- V-Arrangement
- We are trying to get away from a planned to a predictive maintenance



Why is the filler stopping?

- Shards in machine, bottles get stuck / are falling down
- Synchronization problems, engine failures
- Looking at amperages of the involves engines
- Trying to find unusual patterns and assign them to specific problems



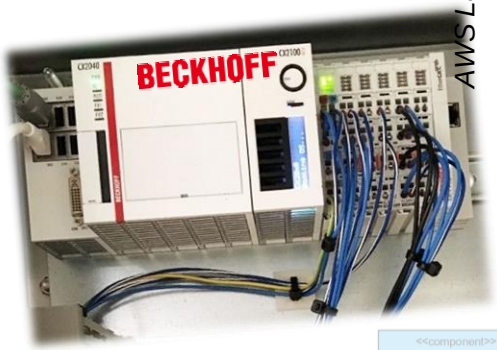


What do we need?

- Syskrons Edge Device “ReadyKit”
- Connection to up to 10 machines
- Reading the PLC raw data
- Transfers data to AWS Cloud Platform to develop and train algorithms
- Deployment of ML models on “ReadyKit”
- Processing data in time to predict failures, machine stops

Predictive Maintenance

Architecture



Machine Learning: Share2Act

- AWS IoT Greengrass Deployment
- Jenkings Pipeline (Continuous Deployment)
- Bitbucket (Codemanagement)
- ML-Service/Application (Python)

Bitbucket

GUI Deployment

- App: Anomaly Detection

AWS S3

Gateway Internet / S3

MQTT

AWS Lambda Code

MQTT

JSON

LAN; TCP/IP

Edge Device Data

- Raw Data
- Results/Scoring/Alerts

Databases Augustiner

Gateway Intranet

LAN

OPC-UA; TCP/IP

PVI; TCP/IP

Data Logger

OPC-UA Server

iba

ReadyKit

AWS Lambda

influxdb

Function: DS-on-Edge
AWS IoT Greengrass

Data Storage (Buffer)

Device Management

Data Acquisition Service (DAS)

SPS
S7 300

SPS
B&R

PLC Data (B&R)

- Motor current
- Motor speed
- Drag error

PLC Data (S7)

- Operating states
- Product information (From WS interface)

Asset
Starwheel

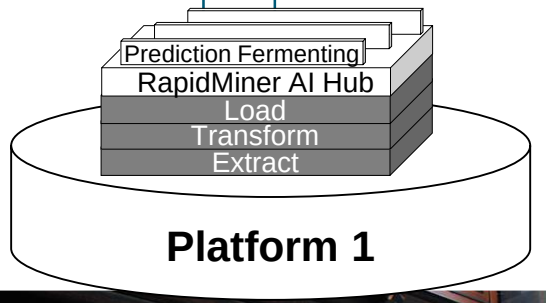
Motor

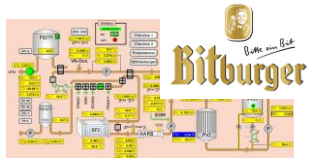
Further Informationen

Cyber-Physical Brewing Lab

INSTITUT FÜR INNOVATION UND TECHNIK

ML2KMU
- Kompetenzentwicklung für produzierende KMU
- Workshop im Labor
- Data Science zum anfassen



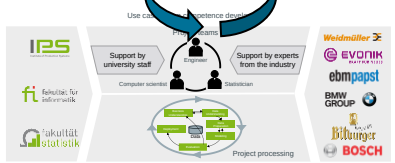


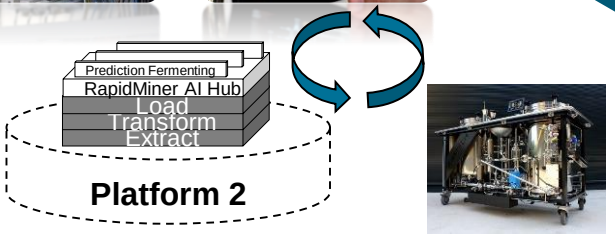
RIF Institut für Forschung und Transfer

DaPro
- Domänenwissen
- Reale Use Cases
- Unterstützung in Aufbau und Betrieb des Labors

Universitäre Lehre
- Lehrveranstaltung „Industrial Data Science“
- Data Science in Theorie und Praxis für Studierende

IPS Institut für Produktionssysteme





UTS Sydney
- Aufbau physischen und Digitalen Zwillings an UTS
- Aufbau eines internat. Forschungsnetzwerks

UTS

Takeaways

Key Learnings and Call for Action

- Be aware of your data quality as it determines limits and possibilities of data analysis!
- Start low and gain hands-on-experience on your data and IT systems!
- Build interdisciplinary teams und embed ML in your organizational structure!

- Within the DaPro project, ML helped to:
  - Use the resource malt more sustainable by predicting the yield and analysing multivariate influencing variables of malt mixtures and process parameters
  - Predict lautering times on the basis of malt analyses
  - Carry out multivariate, holistic analyses of the filtration process by using NIR sensor data
  - Identify causes of filler-revant stops and prevent downtimes in filling systems through anomaly detection
  - Optimise recipes based on ML and customer feedback in Cyber Physical Brewing Lab of RIF
  - Develop ML competencies in the brewerys in order to be able to carry out future projects independently
- **> 50 other use cases were identified and not worked on yet!**

- Help us to validate the Reference Architecture!
  https://forms.office.com/r/UHdE9eC00U

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Contact


René Wöstmann


rene.woestmann@rif-ev.de


www.dapro-projekt.de


+49 231 9700 712