AI and Fraunhofer-Chalmers Centre

2019-01-31

Mats Jirstrand, Assoc Prof, PhD
Head of Department Systems and Data Analysis

Emil Gustavsson, PhD
Business Area Leader, Machine Lerning and AI

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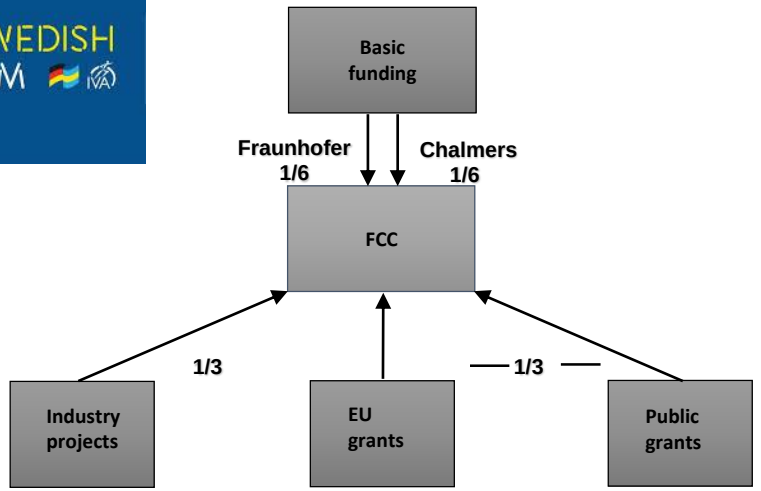
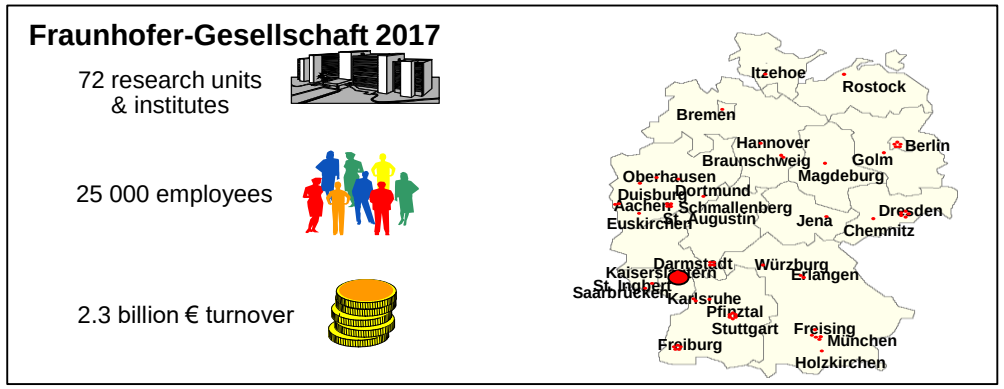
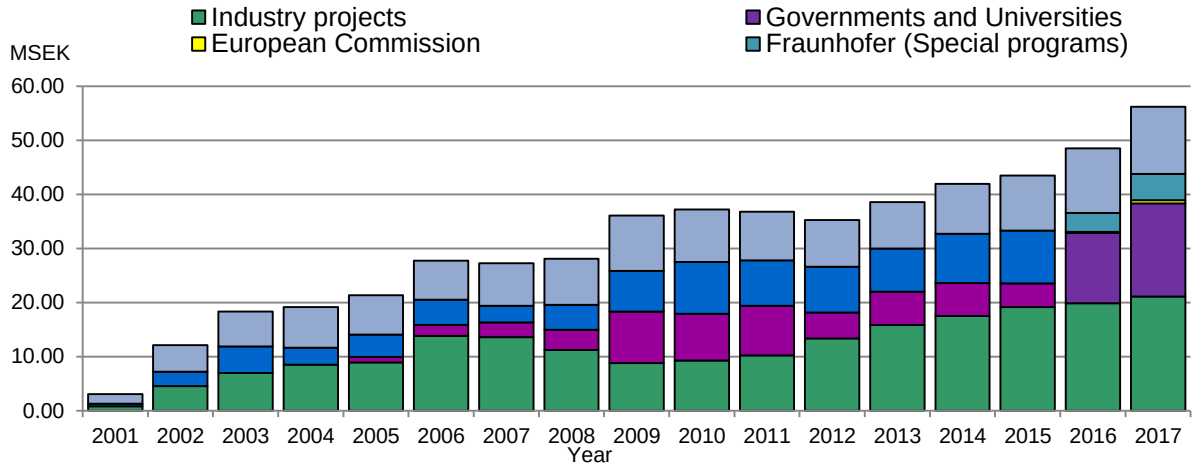
FRAUNHOFER-CHALMERS CENTRE

- Founded September 2001 by Fraunhofer and Chalmers
- Offers applied mathematics for a broad range of industrial applications
- Projects defined by companies and public institutes on a commercial basis
- Pre-competitive research and marketing with financing from our founders
- Systems and Data Analysis, Geometry and Motion Planning, Computational Engineering

GERMAN SWEDISH TECH FORUM







Chalmers AI Research Center (CHAIR): 317MSEK 2019-2028 + industrial partners

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Geometry and Motion Planning

The department develops simulation technology for automatic path-planning and line-balancing, sealing, virtual paint, flexible materials, metrology, and intelligently moving manikins.

Computational Engineering and Design

The department works on numerical methods for fast algorithms and engineering tools to support virtual product and process development. Applications include fluid dynamics, structural mechanics, and electromagnetics.

Systems and Data Analysis

The department offers competence in dynamical systems modeling, pharmacometrics, systems biology and electrophysiology, machine learning, AI, and big data analytics.

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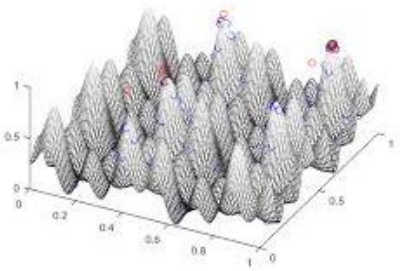
TOOLS & TECHNOLOGY

- Machine Learning
  - Classification & Prediction (SVM, k-means, LASSO, SOM, MDS, GPR)
  - Kernel methods
  - Reinforcement learning
  - Deep neural networks (AE, CNN, RNN)
  - Bayesian optimization
  - Active learning
- Systems & Control Theory
  - DEs, ODEs, SDEs, …
  - Stability, sensitivity, ...
  - Feedback & adaptive control
  - System identification
  - Optimal control

- Probability & Stochastics
  - Monte Carlo methods (MCMC, SMC)
  - Probabilistic programming
  - Gaussian processes
  - Bayesian networks (PGM)
  - Joint Modeling (time-series & time-to-event data)
- Optimization
  - Gradient based methods
  - Automatic differentiation
  - Sparse linear algebra, ...



- Python
- R – Statistics
- Mathematica
  - Numerics/Symbolics
  - Wolfram Workbench (IDE)
- Matlab – Numerics
- BDA
  - Spark, Storm, MXNet, TensorFlow, …
  - AWS, Google Cloud, Azure
- C++
- Java, Scala, JavaScript, Erlang, NoSQL, Apache, Nginx, React, Angular, CUDA, …

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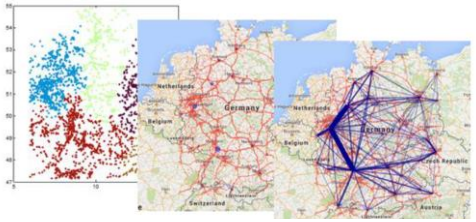
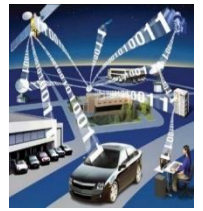
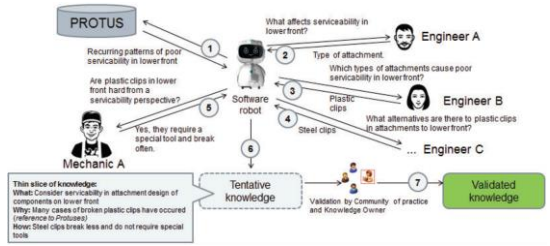
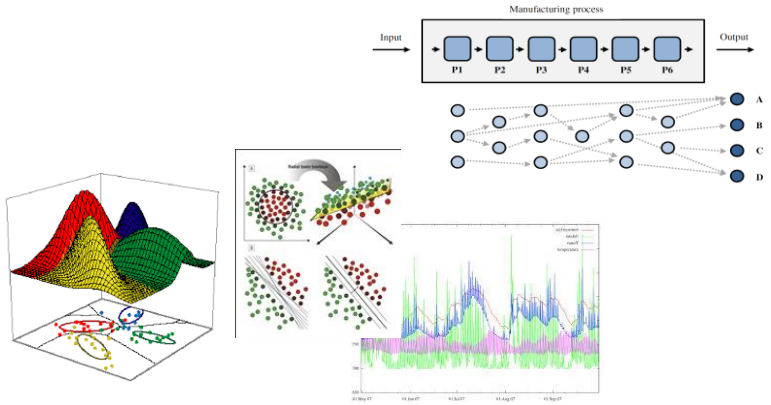
APPLIED MACHINE LEARNING, AI, AND BIG DATA ANALYTICS

- Digitalization in Manufacturing
  - Root Cause Analysis of Quality Deviations in Manufacturing Using Machine Learning (RCA-ML), SKF, FlexLink, Chalmers
  - Smart Assembly 4.0, Chalmers/Wingquist Lab
  - SUstainability, sMart Maintenance and factory design Testbed (SUMMIT), Scania, Siemens, CEVT, SAAB, SSAB, Chalmers, …
- Big Automotive Data Analytics
  - Fleet telematics big data analytics for vehicle Usage Modeling and Analysis (FUMA), Scania CV
  - On-board Off-Board Distributed Data Analytics (OODIDA), Volvo Cars, AB Volvo, Alkit, Chalmers
  - Machine Learning for Engineering Knowledge Capture (MALEKC), AB Volvo, Chalmers
- AI in Life Science
  - Dynamical systems learning and “joint modeling”, AstraZeneca, Merck, Grunenthal, …
  - Machine learning for pre-clinical cardiotox to clinical outcome prediction, Boehringer-Ingelheim









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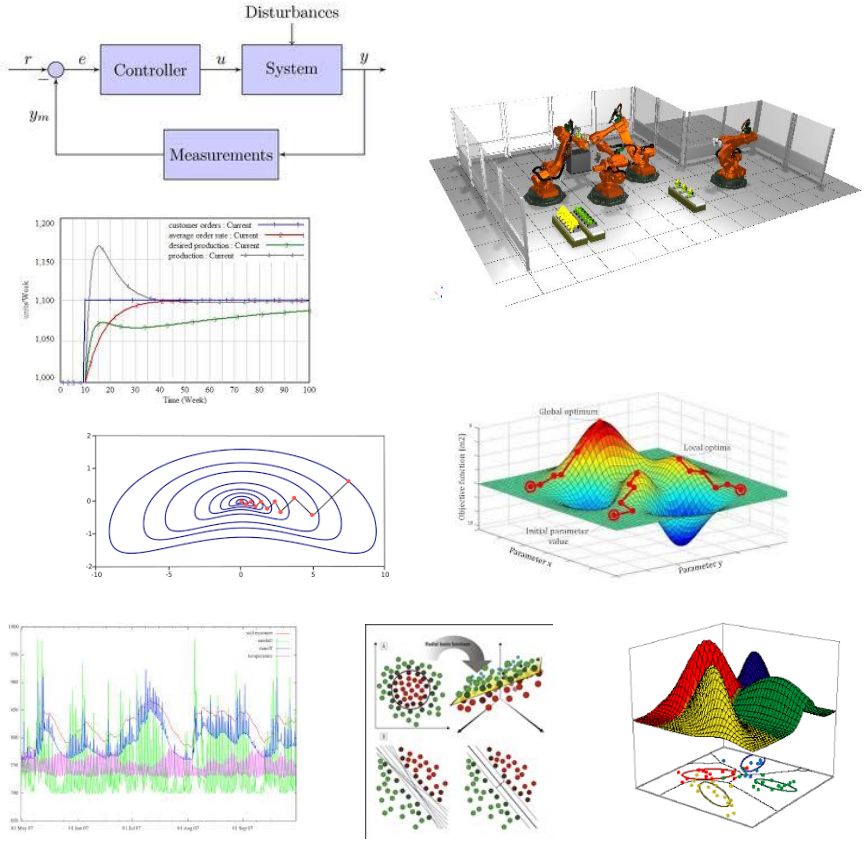
APPLIED MACHINE LEARNING, AI, AND BIG DATA ANALYTICS

- Modeling
- Simulation
- Optimization
- Data Analytics



Very useful components for safe, efficient, explainable applied AI and ML

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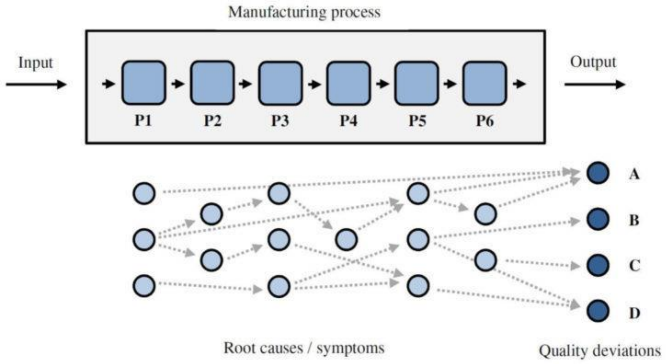
ROOT CAUSE ANALYSIS OF QUALITY DEVIATIONS IN MANUFACTURING USING MACHINE LEARNING (RCA-ML)

VINNOVA Den smarta digitala fabriken 2016-2019

Participants: *FCC, Chalmers, SKF, Flexlink*



SKF

- Time series analysis using LSTMs for detecting degradation in grinding discs
- Regression modeling with random forests and neural networks for finding causal relations between process parameters and production quality
- Bayesian networks for root cause analysis using expert knowledge

Flexlink

- Detecting and correcting errors in item counters using fast convolutional neural networks
- Development of simulators for work in progress (WIP) counters

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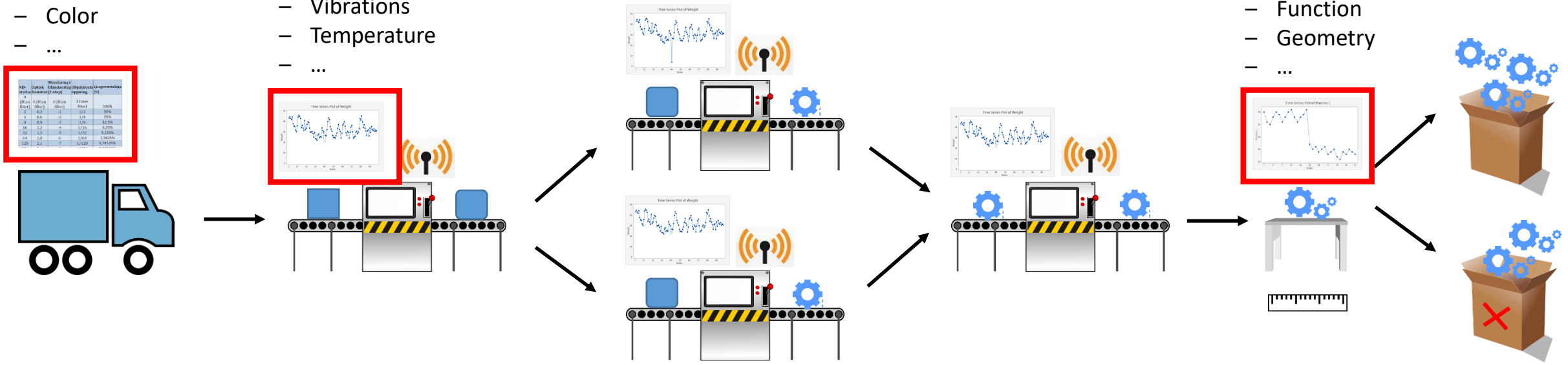
MANUFACTURING – MACHINE LEARNING & AI

- Geometry
- Color
- …

- Speed
- Vibrations
- Temperature
- …

- Function
- Geometry
- …



Manufacturing process line

- Equipment (state-of-health)
- Products (quality)
- System (overall equipment efficiency)

Manufacturing – Data

- Different purpose – different data

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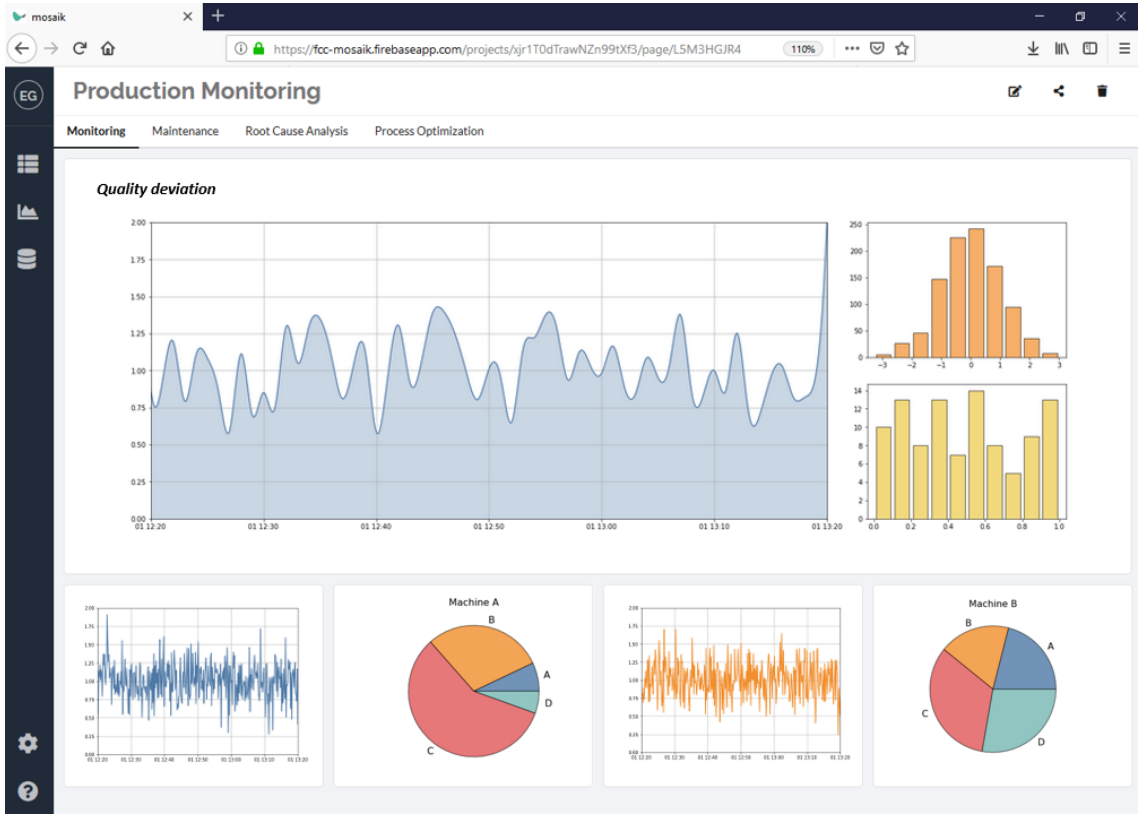
WHAT IS THE PURPOSE OF AI IN MANUFACTURING?

- Monitoring & Diagnosis
- Maintenance
- Root Cause Analysis (RCA)
- Process Optimization

MONITORING AND DIAGNOSIS

- Visualization of time-series data
- Relevant and informative HMI important

- *Methodologies:*
  - Anomaly detection algorithms
  - Change point detection
  - State classification of machines



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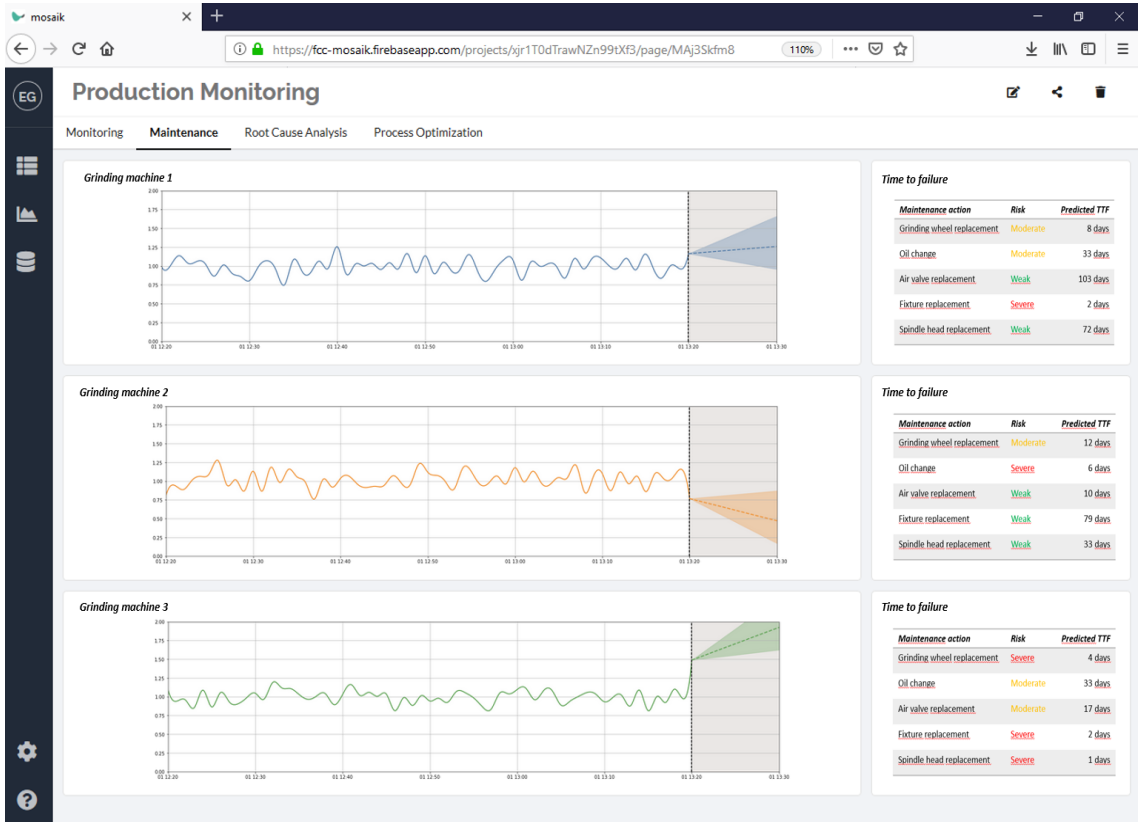
MAINTENANCE

- Predictive maintenance
- Modeling state-of-health of components

- *Methodologies:*
  - Time series analysis
  - Time to failure analysis / Survival analysis
  - Joint time-series and failure modeling



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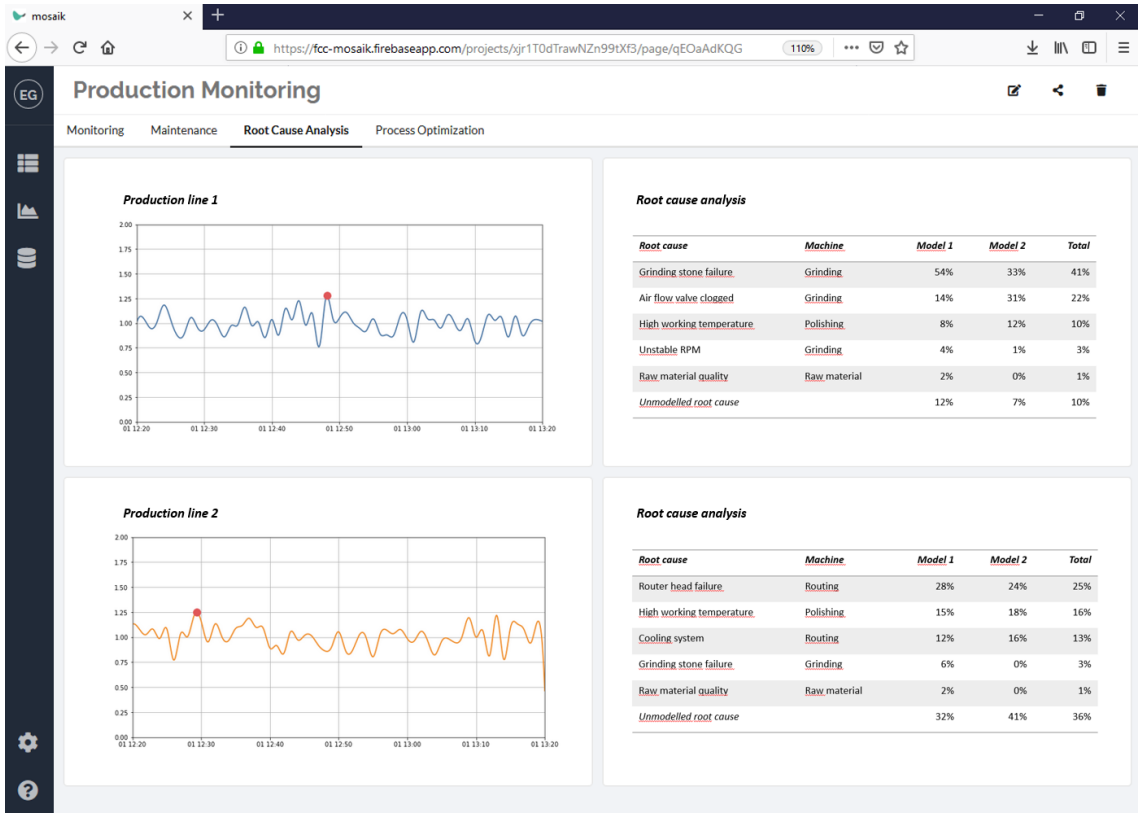
ROOT CAUSE ANALYSIS

- Determining the root-cause of an observed quality deviation or failure
- Inference using data from products (quality) and data from production (equipment)
- *Methodologies:*
  - Bayesian networks
  - Causal inference



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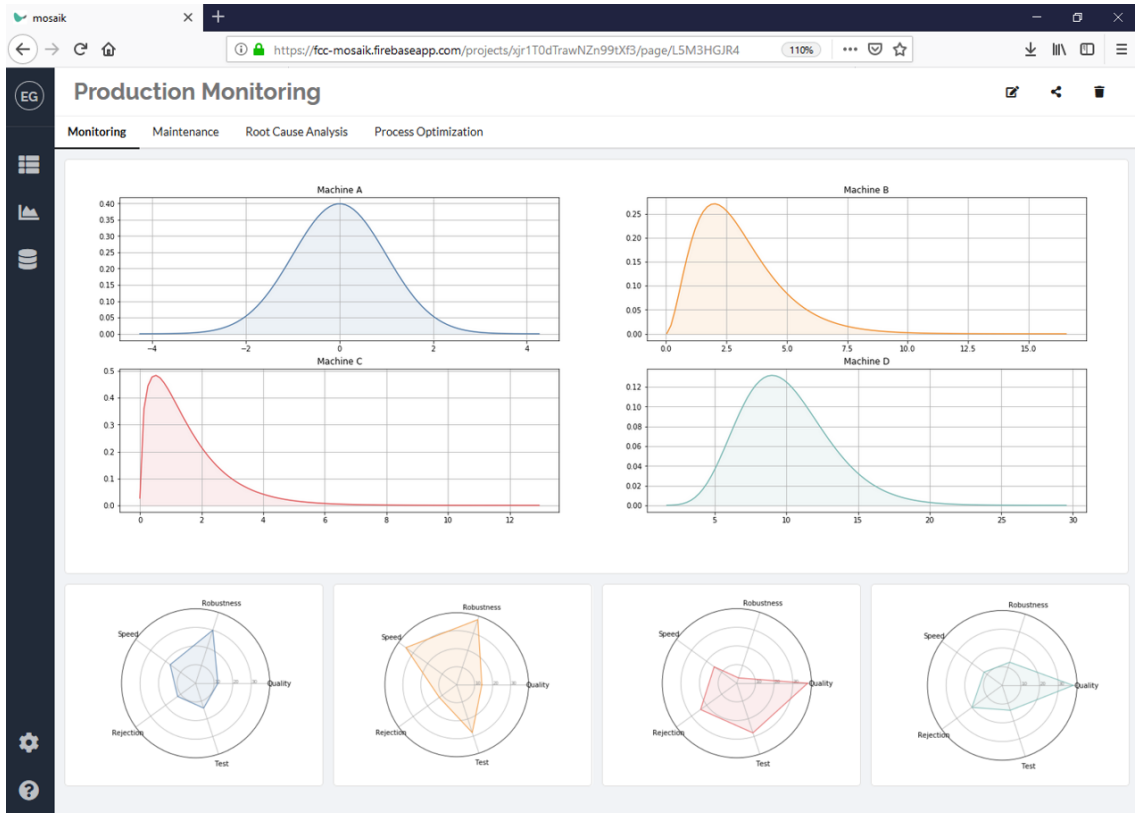
PROCESS OPTIMIZATION

- Modeling the relation between process parameters and product quality
- Using model for optimizing process settings for each product type

- *Methodologies:*
  - Regression / Classification
  - Black box optimization / Simulation based optimization



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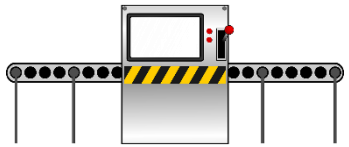
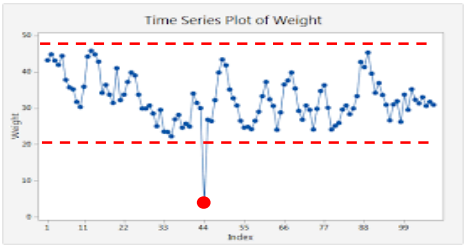
MAINTENANCE

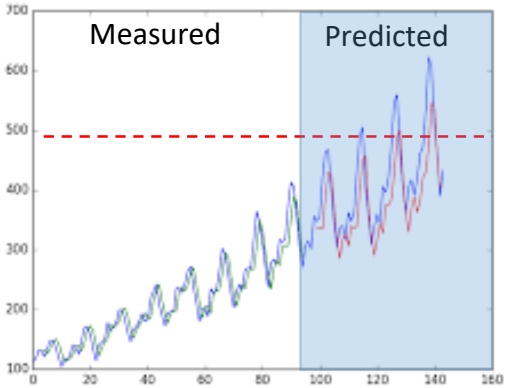




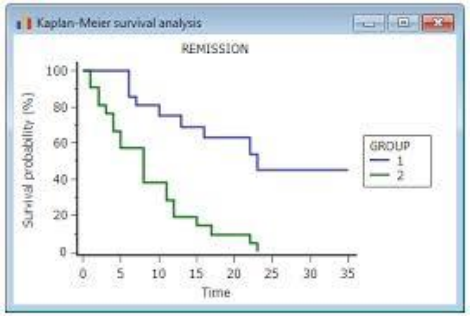
- State-of-health of equipment
  - Simple: Thresholds
  - Advanced: Modeling for Classification & Prediction of problems
    - Models: ARX, MA, ARMAX, RNN, …

$$y(t+1) = f(y(t), y(t-1), \dots, u(t), u(t-1), \dots; \theta) + e(t)$$

    - (i) Fit models to historical data (offline)
    - (ii) Compute future expected values of process variables (online)
    - (iii) Take action if outside safe region (online)



  - Advanced: Events modeling
    - Models: survival/reliability analysis (MTBF, hazard functions)



  - Advanced: Joint time-series & events modeling
    - Models: time-series models + survival/reliability models

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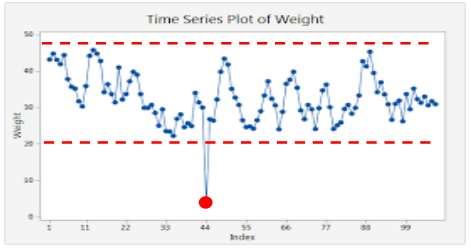
JOINT TIME-SERIES AND EVENT MODELING



- Data:
  - Time-series – machine variables (speed, pressure, temperature, …)
  - Events – abrupt changes in machine state-of-health (break down, thresholds, …)

- Models:
  - ARX, MA, ARMAX, RNN, …

    $y(t+1) = f(y(t), y(t-1), \ldots, u(t), u(t-1), \ldots; \theta) + e(t)$

  - Survival function:

    $S(t) = Pr(T>t)$

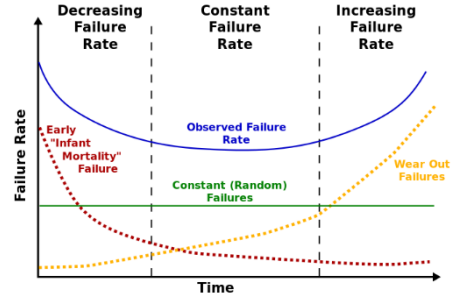
    prob of survival until *t* or later

    Hazard function:

    $h(t) = Pr(t \le T < t+dt \mid T>t)/dt = -S'(t)/S(t)$

    event rate at t conditioned on survival until *t* or later

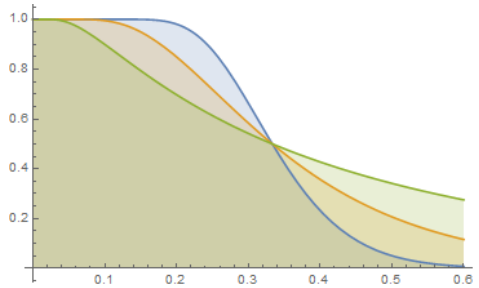
    $$S(t) = \exp\left(-\int_0^t h(\tau)d\tau\right) = \exp(-\Lambda(t))$$



  - Joint model:

    $h(t; a, b, f) = Pr(t \le T < t+dt \mid T>t, \{y(\tau)\}_0^t)/dt = h_0 \exp(a\, y(t) + b\, y'(t))$

    $$S(t) = \exp\left(-\int_0^t h(\tau; a, b, f)d\tau\right) = \exp(-\Lambda(t; a, b, f))$$



- Given operating machine conditions: when to schedule maintenance to avoid failure with probability 0.99?

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CONTACT

- Mats Jirstrand, mats.jirstrand@fcc.chalmers.se

- Emil Gustavsson, emil.gustavsson@fcc.chalmers.se

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