# Process Understanding & Improvement with Data Analysis and AI

Stefan Biffl Sebastian Kropatschek Dietmar Winkler
Kristof Meixner Stefan Fenz Clemens Heitzinger

Workshop 13.2.2025

# Debugging a Welding Process with Systematic Defect Analysis

**Find 100 needles in a haystack**

Sebastian Kropatschek

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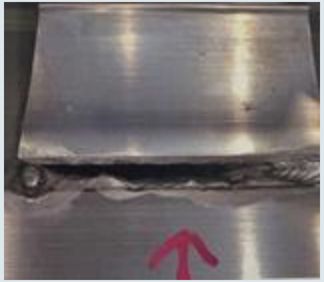
# Reduce Quality Issues with Expert Guidance

Expert


Defect



Issue: Bad Welding

Manual Rework

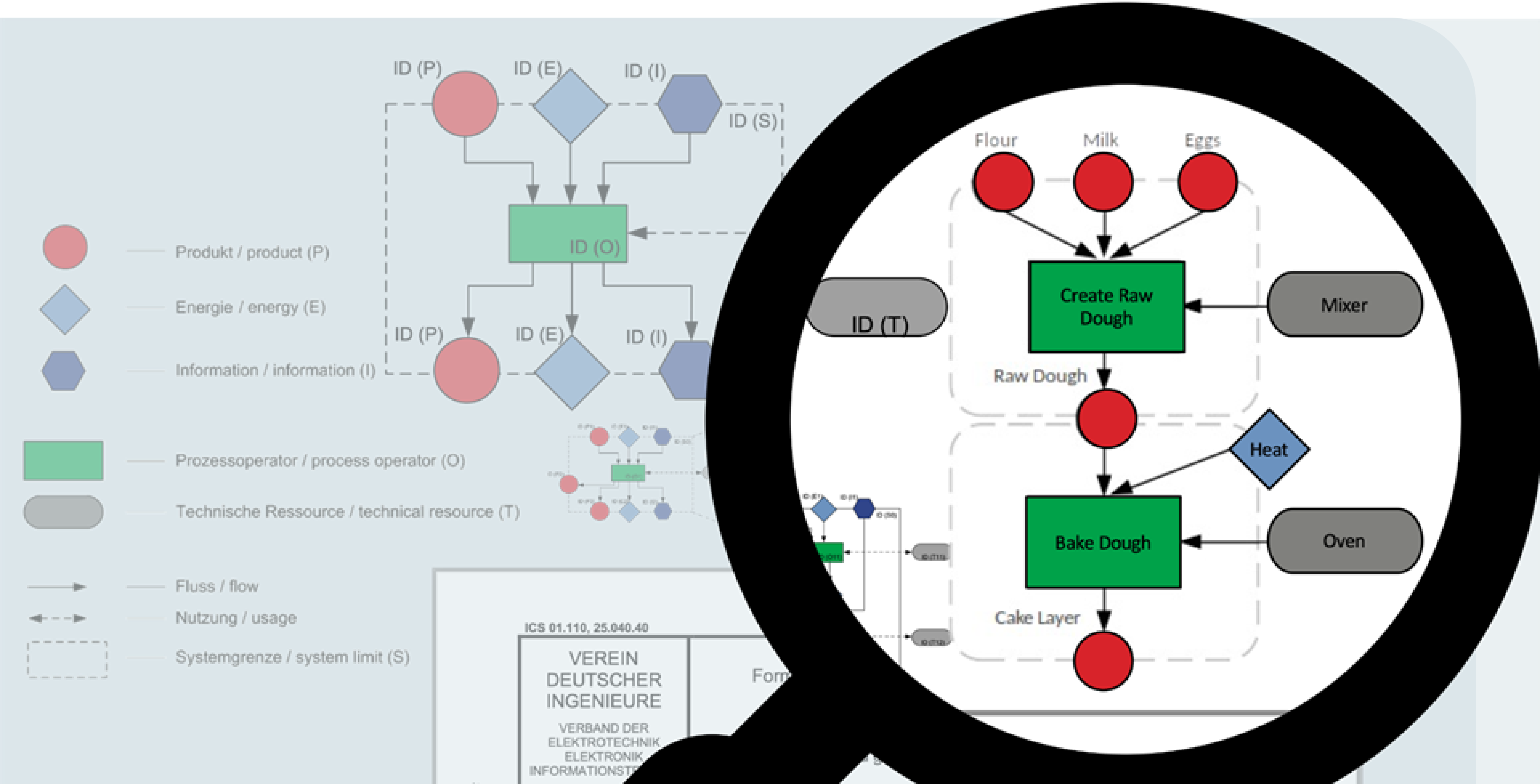
Scrap

Downtime

Problems in laser welding cells and lines were identified and fixed in structured and efficient ways.

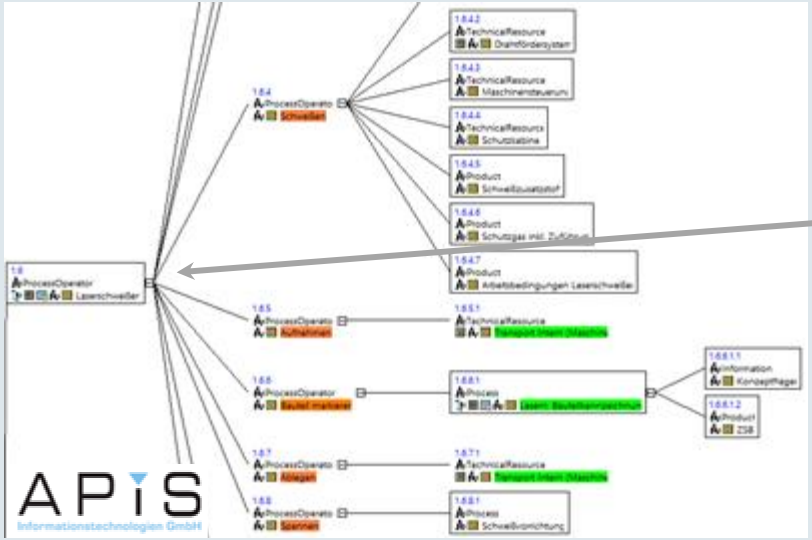
Cost reduction in the order of several 100 kEUR per welding cell/line per year.

# Product, Process, Resource (PPR) Asset Network

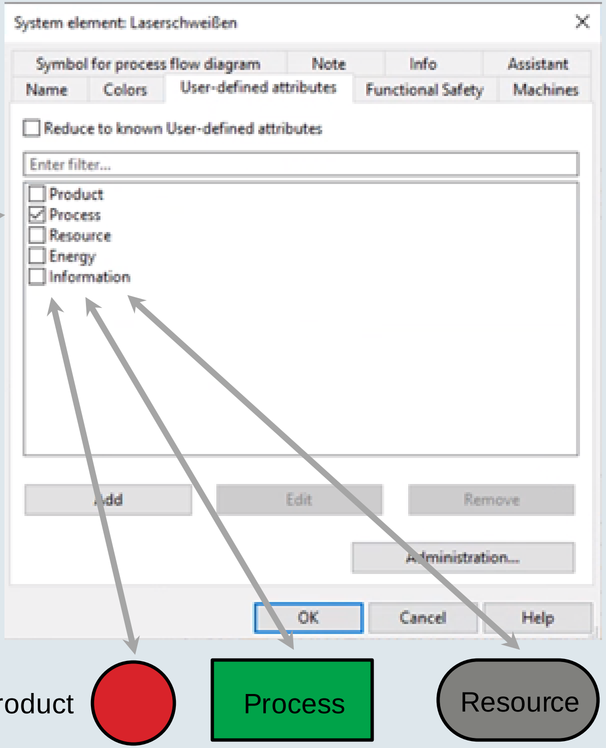


# FMEA Tool APIS already includes PPR Assets

**FMEA**: **F**ailure **M**ode and **E**ffects **A**nalysis




**PPR**: **P**roduct, **P**rocess, **R**esource




Product

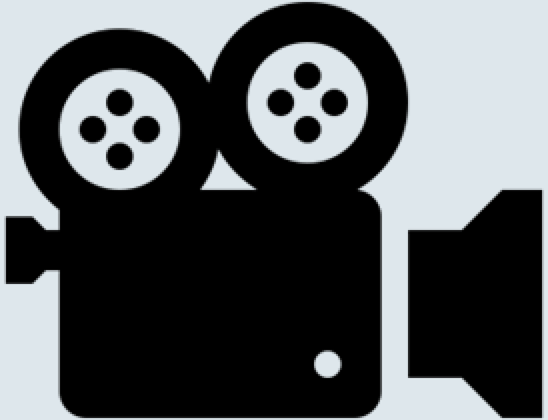
Material

Method

Machine

**Feedback loop from FMEA to production and back**

# Expert Guidance: Reference Implementation



# Expertise – Senior Asset Data Analyst

DI Sebastian Kropatschek, MSc - Austrian Center for Digital Production (ACDP)

- ➢ Background
  - Senior researcher at *Comet Excellence Centers* for *Digital Production* (CDP)
  - Process analysis and improvement projects with Neuman Aluminium, VW, Kapsch, Post, ÖBB, etc.
  - Diploma degree in Technical Physics with a focus on Quantum Physics from TU Wien, supervised by Anton Zeilinger
- ➢ Expertise
  - Advanced Technologies: Cause-effect analysis, knowledge graphs, machine learning, quantum physics.
  - Industrial Engineering Experience: Automotive, aerospace, and other sectors.
  - Lead for expert teams to solve complex industry challenges.

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# Process Improvement based on Data Integration and Analysis

## Tap 1,000 glasses of beer

Dietmar Winkler

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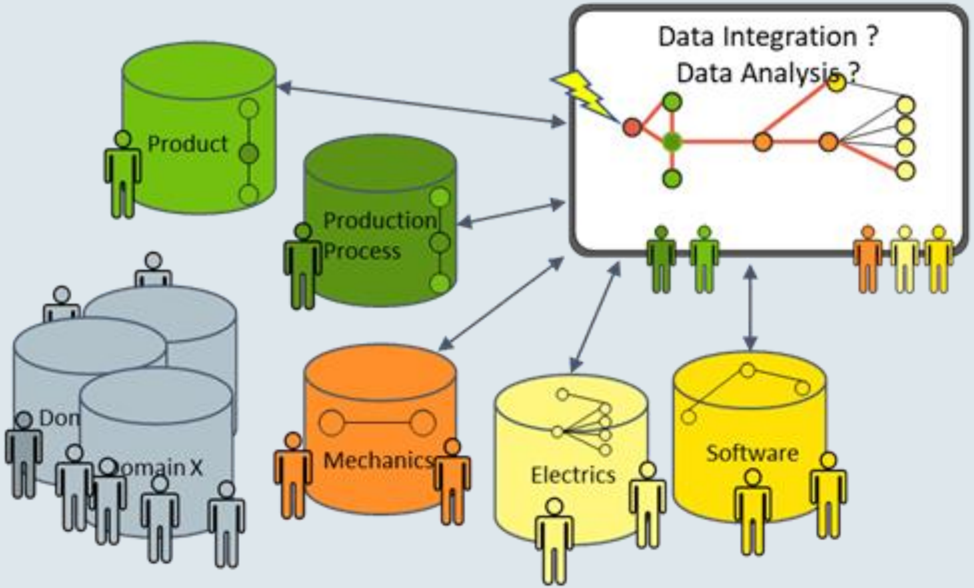
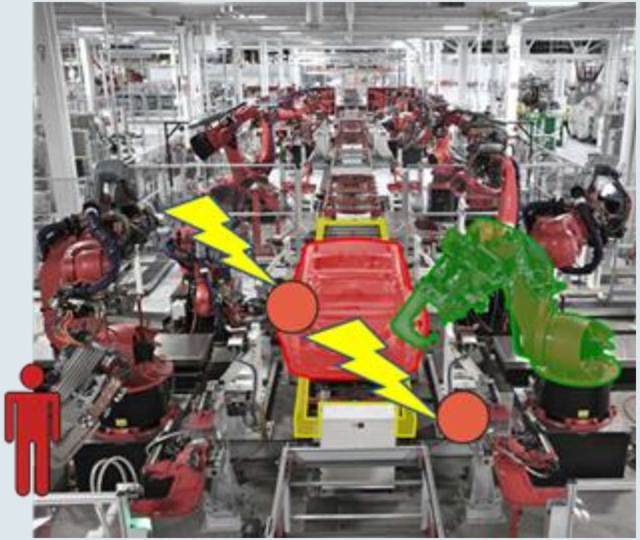
# Challenges



**Context:** Production Automation Systems or related fields.

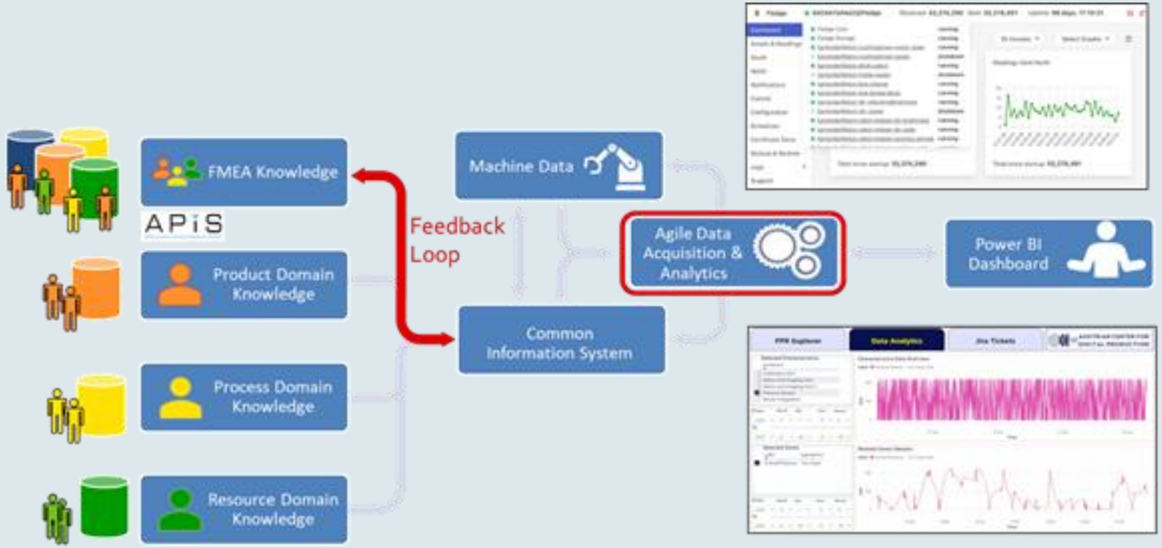
**Challenges:**

- ➢ Risk assessment is often not updated with sufficient frequency.
- ➢ Heterogeneous data sets are difficult to collect and integrate.
- ➢ Scattered engineering knowledge hinders a broad overview.
- ➢ Data analysis often takes considerable effort of experts.

# Success Story: Agile Data Acquisition & Analysis

**Use case: Tap 1,000 glasses of beer**

- ➢ Central Information System as foundation for AI applications.
- ➢ Efficient and agile data collection.
- ➢ Flexible data analysis and dashboards.
- ➢ Continuous process improvement.




# Expertise – Senior Quality Data Analyst

DI Dr. Dietmar Winkler, *Center for Digital Production*, and
TU Wien, Inst. of *Information Systems Engineering*.

- Background
  - Business informatics: Software and system process improvement, quality assurance and management.
  - Area manager at the Center for Digital Production (CDP) for data integration and analytics for digital production.

- Expertise
  - (Software) Quality Assurance and Risk Management with FMEA.
  - Data integration for efficient monitoring and analysis in CPPS.
  - ISO 9001 certification support at Continental.
  - Data analysis projects with Neuman, Volkswagen, ÖBB, Post etc.

Winkler et al, Industry 4.0 Asset-Based Risk Mitigation for Production Operation, Int. Conf on Automation Science and Engineering, 2021.
Winkler et al, Modell-unterstützte Qualitätssicherung für das Engineering industrieller Produktionssysteme, In: Handbuch für Industrie 4.0, 2017, 2024.

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# Validating Flexible Manufacturing Processes

## Bake 100 different kinds of cake

Kristof Meixner

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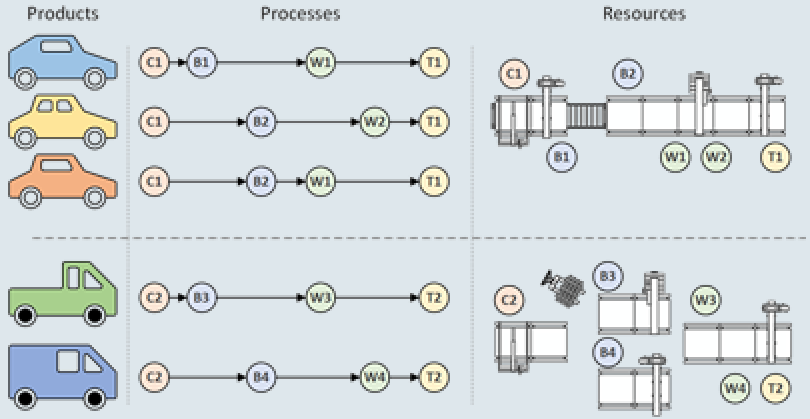
# Challenges: Flexible Manufacturing

**G** ***Improve engineering knowledge and artifact reuse*** for flexible manufacturing

**C** ***Insufficient systematic knowledge representation*** of manufacturing variability

**C** ***Laborious knowledge elicitation*** of 'containerized' variability knowledge

**C** ***Hard validation of manufacturing configurations*** impedes scaling and transfer



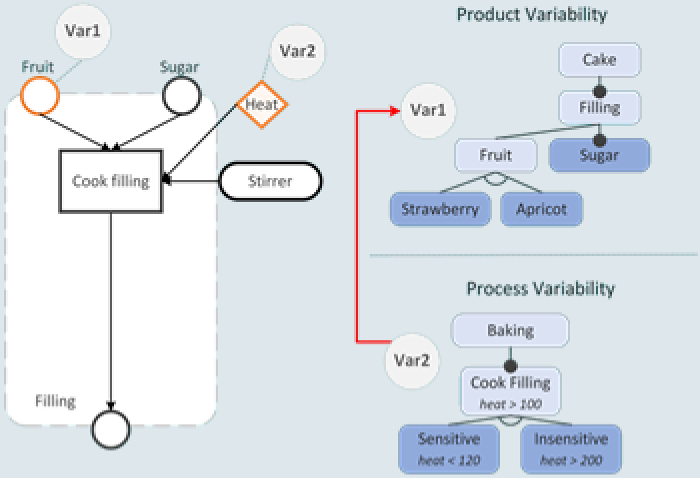
# Success Story: Variant Domain Analysis

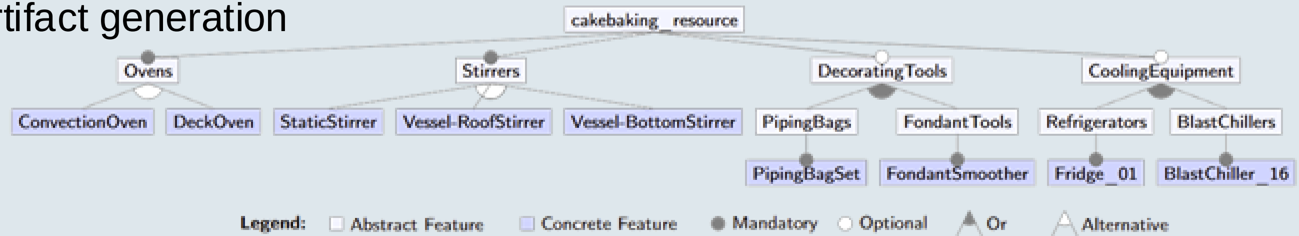
G Improve the ***reuse of engineering artifacts and production configuration*** for scaling up flexible manufacturing.

S ***Structured knowledge representation*** of products, processes, and resources in manufacturing variants.

S ***Exploration of manufacturing configurations***

S ***Validation of interdependent manufacturing configurations*** and artifact generation



# Expertise – Senior Asset Variant Analyst

DI Dr. Kristof Meixner, TU Wien, Inst. of *Information Systems Engineering*

- ➢ Background
  - (Business) Informatics: Efficient Reuse and Variability Management of Families of Production Systems [1]
  - Researcher in the *Christian Doppler Research Lab SQI*
  - *Reuse and variability analysis and modeling* with industry companies such as STIWA and *Volkswagen*.
- ➢ Expertise
  - *Senior Software Engineer* in (open-source) Software Development.
  - Transferring knowledge from one machine to another, and from one factory to another.
  - Scaling up flexible manufacturing with systematic reuse.

[1] Meixner et al.: Variability modeling of products, processes, and resources in cyber-physical production systems engineering. J. of Systems and Softw., 2024.

# Data Analysis for Life Sciences

**Classify crops on 100 satellite pictures**

Stefan Fenz

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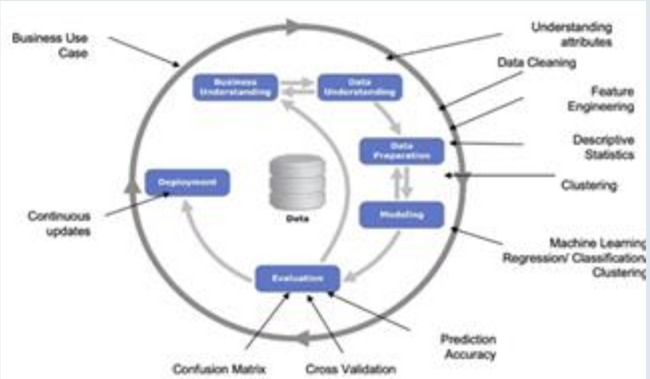
# Success Story: Cropsense

# Success Story: Cropsense

- ➢ Context: auditing crop production in defined geographical areas.
- ➢ Goal: automatically recognize crops on satellite pictures

- ➢ Challenges:
  - ○ Freely available satellite data (Sentinel-2) does not have sufficiently high resolution.
  - ○ Clouds prevent continuous monitoring.
  - ○ Preparation of satellite data requires understanding of the crops to be detected.




- ➢ Processes that Procando method elements and tools successfully supported
  - ○ Bridging crop and data science expertise
  - ○ Understanding the risks of erroneous crop classification

# Expertise – Senior Data Analyst

Dr. Stefan Fenz, TU Wien, Inst. of *Information Systems Engineering*

- Background
  - Senior scientist and lecturer at TU Wien.
  - Key researcher at *Secure Business Austria* Research.
  - Conducted several industry and research projects in AI applications and decision support systems.
  - Co-founder of *Xylem* Technologies.

- Expertise
  - Information Systems Engineering
  - Semantic technologies (ontologies)
  - Decision support systems
  - Machine learning

# Process Optimization with Reinforcement Learning

**Control 100 Turbine Starts**

Clemens Heitzinger

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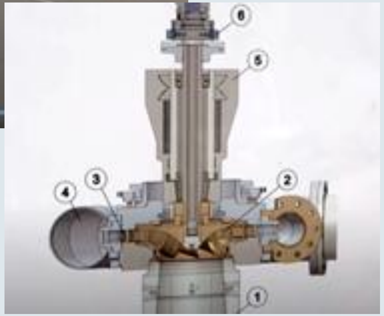
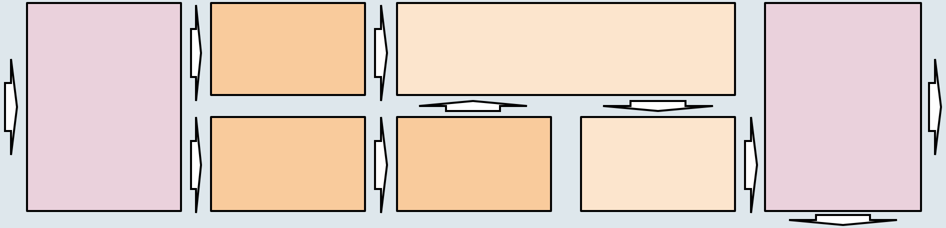
# Process Optimization – Challenges







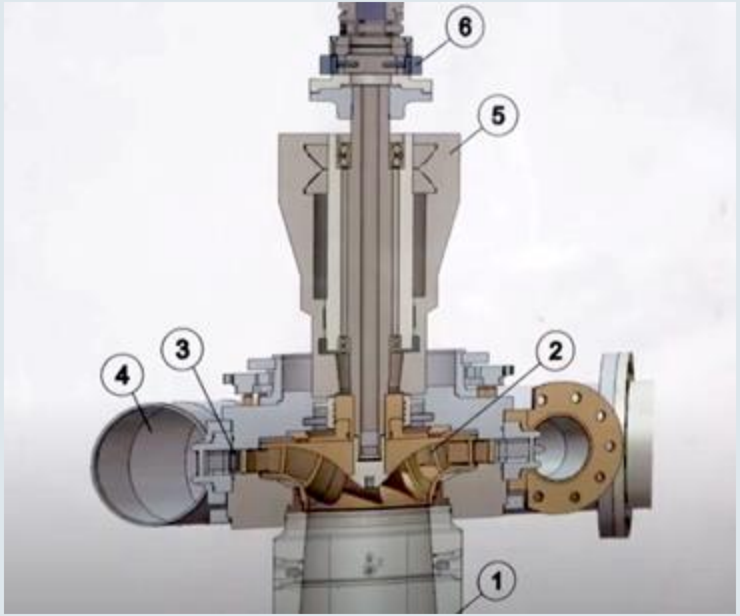
- Bake 100 Cakes –
  **> Drive 100 Routes.**
  **> Make 100 Diagnoses.**
  **> Control 100 Turbine Starts.**

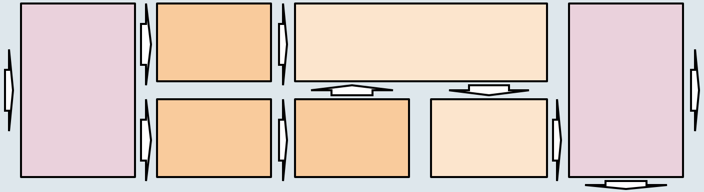
**Challenges:**

- Information silos:
  QM, physics, IT, machine vendors, medical knowledge.
- Local optimization may lead to global quality problems.
- Insufficient data on special cases > blind spots in process understanding & improvement.

Heitzinger et al., Superhuman performance on sepsis MIMIC-III data by distributional reinforcement learning. PLOS ONE, 17(11):e0275358/1–18, 2022.

# Turbine Process Optimization – Best Practices



- ➢ Bake 100 Cakes –
  **> Control 100 Turbine Starts**.
- ➢ Optimize power grid resilience.
- ➢ Reduce wear and tear.
- ➢ Reduce costs.

**Best Practices***:*

- ➢ Bridging information silos.
- ➢ Understanding risks that come from causes in different domains.
- ➢ Backtrack asset dependencies.
- ➢ Agile scenario-based process observation, improvement.

**Impact:**

- ➢ More effective and efficient Data Analysis and AI projects.
- ➢ Better testing and monitoring in a systems engineering team.

Heitzinger et al., Adapting to the “open world”: the utility of hybrid hierarchical reinforcement learning and symbolic planning. In Proc. 2024 IEEE International Conference on Robotics and Automation (ICRA 2024).

# Expertise – Process Optimization with AI

Prof. Dr. Clemens Heitzinger, TU Wien,
Inst. of *Information Systems Engineering*.

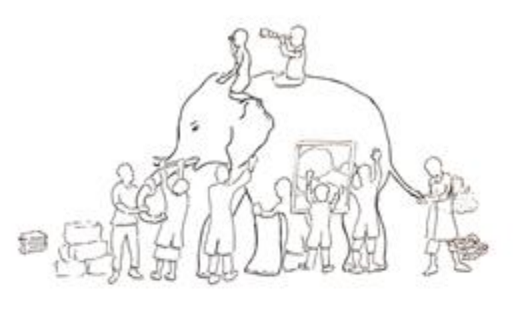
- Background
  - Co-Director of the *Center for Artificial Intelligence and Machine Learning* (CAIML).
  - Process understanding with Machine Learning.
  - Process improvement with Reinforcement Learning.
  - Language Processing with Generative AI: Large Language Models.
  - Process optimization projects in autonomous driving, healthcare, industry, energy production balancing, etc.

- Expertise
  - Information Systems Engineering to answer key stakeholder questions.
  - Efficient Machine Learning.
  - Process analysis and improvement for human and machine teams.

# Process Understanding & Improvement

with Data Analysis and AI

**Introduction**



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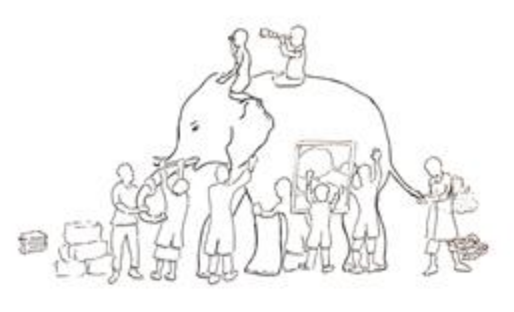
# Process Understanding & Improvement

with Data Analysis and AI



**Introduction**

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# Process Understanding & Improvement

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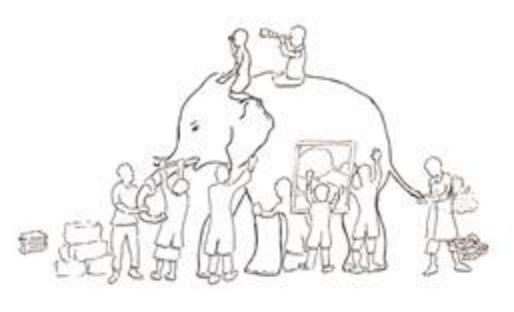

**Introduction**

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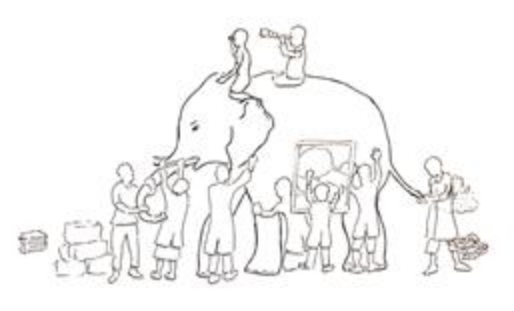

Stefan Biffl

## Bake 100 Cakes

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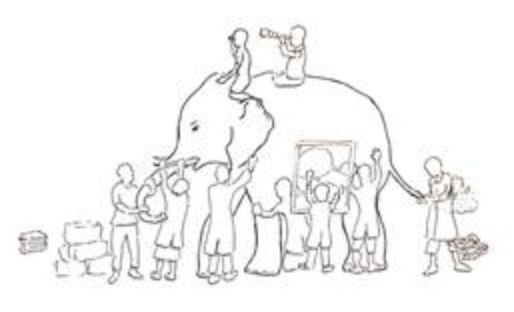
# Process Understanding & Improvement

with Data Analysis and AI

**Introduction**



Stefan Biffl

## Bake 100 Cakes
## Connect Information Silos

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# Expertise - Senior Process and Systems Analyst

Prof. Dr. Stefan Biffl, TU Wien, Inst. of Information Systems Engineering

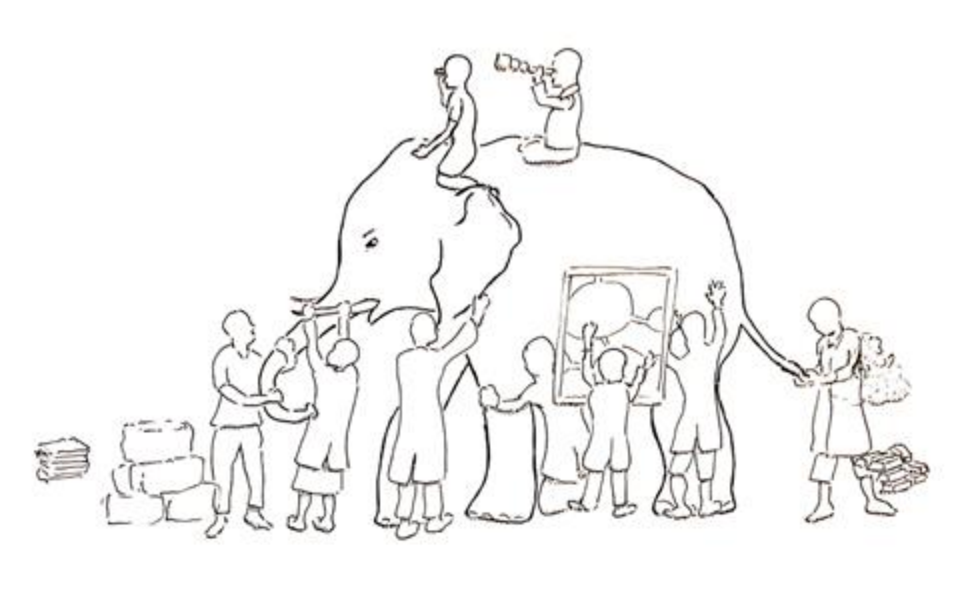
- Background
  - Business informatics: process understanding and improvement
  - Lead of *Christian Doppler Research Lab* module for *Quality Improvement in the Production System Lifecycle*
  - Key researcher at *Comet Excellence Centers* for *Digital Production* (CDP) and *Secure Business Austria* (SBA)
  - Process analysis projects with Volkswagen et al.

- Expertise
  - Information Systems Engineering to answer key stakeholder questions
  - Knowledge representation for human and machine experts
  - Process analysis and improvement for human and machine teams

Biffl et. al, Multi-Disciplinary Engineering for Cyber-Physical Production Systems, Springer, 2017.
Biffl et. al, An Industry 4.0 Asset-Based Coordination Artifact for Production Systems Engineering, Int. Conf. on Business Informatics, 2021.

# Process Understanding with Quality Assurance

Input Quality Assurance



Output Quality Assurance

Too much Waste

➢ Process understanding requires quality assurance measurement
on the inputs to the process and
on the outputs that come from the process.

# A Simple Data Analysis Project

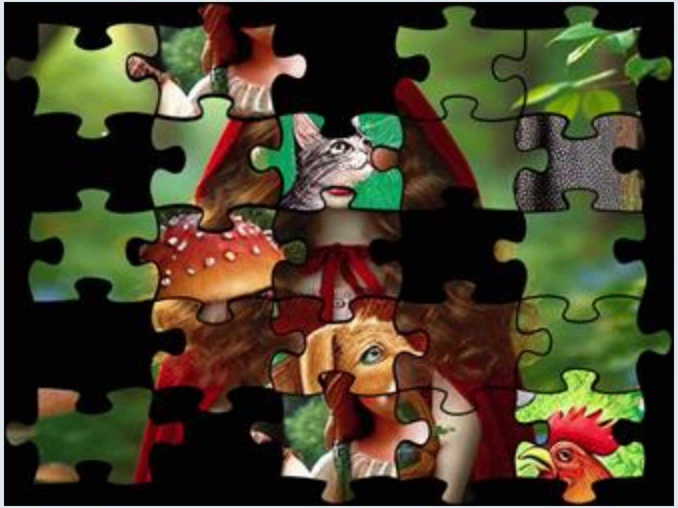
- Start simple: 5x5 puzzle with a target picture.
  - Assemble the puzzle.
  - What is this story about?
  - This looks like an easy task.

# A Simple Data Analysis Project meets Reality

- Start simple: 5x5 puzzle with a target picture.
  - Assemble the puzzle.
- Take away half of the pieces.
  - What is this story about?

# A Simple Data Analysis Project meets Reality

- Start simple: 5x5 puzzle with a target picture.
  - Assemble the puzzle.
- Take away half of the pieces.
  - Exchange further pieces for wrong ones.
  - This is reality from data analysis projects.
  - What is this story about?



# A Real Data Analysis Project meets Big Data

- Start simple: 5x5 puzzle with a target picture.
  - Assemble the puzzle.
- Take away half of the pieces.
  - Exchange further pieces for wrong ones.
  - This is reality from data analysis projects.
- Add 1,200 puzzle pieces that you happen to find in your puzzle storage.
  - Try to find the original 25 pieces without a target picture.
  - This is a data analysis project with big data, but without a clear plan.

# A Big Data Analysis Project meets AI

- Start simple: 5x5 puzzle with a target picture.
    - Assemble the puzzle.
- Take away half of the pieces.
    - Exchange further pieces for wrong ones.
    - This is reality in many data analysis projects
- Add 1,200 more pieces that you
  happen to find in your puzzle storage.
- Ask an AI algorithm to propose “5x5 solutions”.
    - Get several plausible,
      but wrong “solution options”.
- Ask a data analyst to improve your situation: what can they do?
    - How shall they find a needle in the big haystack?
    - How shall they spin straw to gold?
- *What started as a small problem, became a big problem.*

# The Data Analyst and the Shared Data Space

- **The Data Analyst shall answer a question** on a process condition such as “*Is Cake Waste high?*” with the data they receive.

?

- **The *Shared Data Space* is all data available** in an organization, a gold mine, a well-kept storage, or a dump, depending on whom you ask. **Where will the data for analysis come from?**

# Keys to a Simple Data Analysis Project

- You want these 5x5 puzzle pieces
  - that represent the concepts
  - to understand the story.
  - … but ***where are these puzzle pieces?***

- You want access to data
  - that fit to the puzzle pieces, and
  - that the data analyst can understand.
  - … but ***who knows where to find this data?***

- **As the sponsor of a valuable data analysis project, you want answers to these questions.**