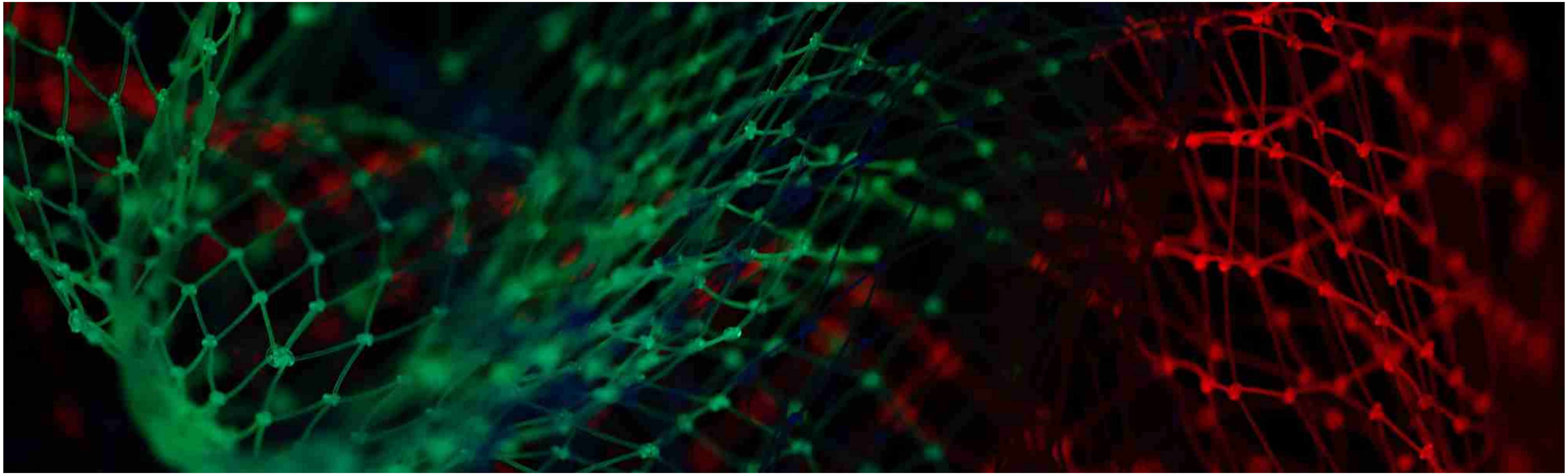
MACHINE LEARNING APPLICATIONS IN PRODUCTION ENVIRONMENTS

Christian Blobner, Uwe Knauer

Seoul, November 8, 2018



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TAKE AWAY MESSAGE

- Manufacturing and process industries can massively benefit from tailor-made data analytics using machine learning and artificial intelligence
- Depending on the starting position, there are different options to make machine learning work
- It is getting easier to collect data in various manufacturing processes and production stages
- Access to data analytics for AI through cloud based services, such as Fraunhofer's Virtual Fort Knox, helps companies in developing on algorithms
- Experience-knowledge can provide value-adding information to support to conventional machine learning methods

The Fraunhofer IFF as a production oriented institute has the experience and skills to address your needs in the field of machine learning applications in production environments

The Fraunhofer Institute for Factory Operation and Automation IFF
Where do we come from

Fraunhofer Institute for Factory Operation and Automation IFF

- Located in Magdeburg, Germany
- 200 Researchers
- €20Mio Research budget p.a.
- International experience on six continents

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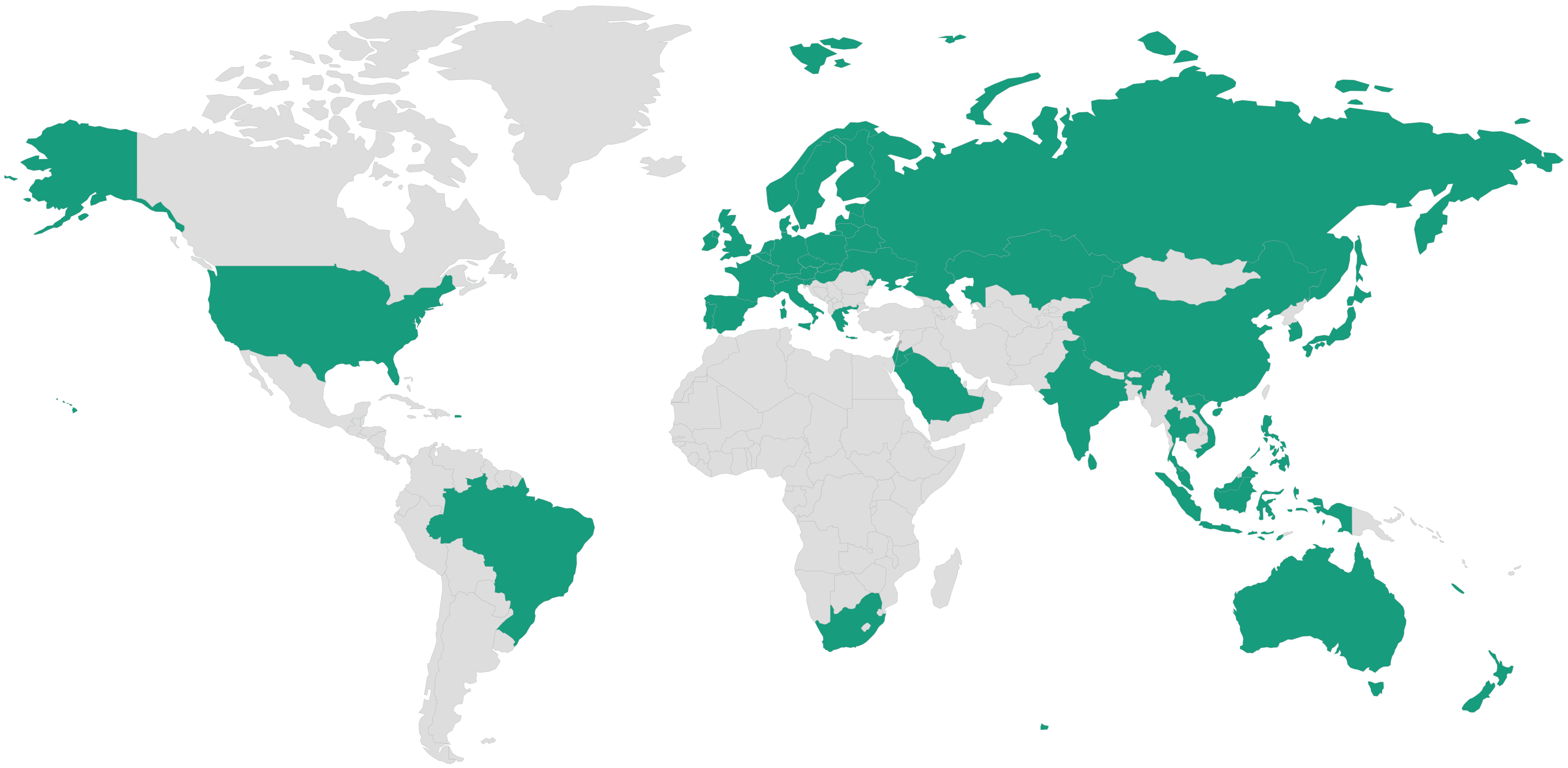
The Fraunhofer Institute for Factory Operation and Automation IFF

Active world wide



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Providing a system perspective on the factory

Fraunhofer IFF Business Units

- Virtual Engineering
- Convergent Infrastructures
- Logistics and Factory Systems
- Material Handling Engineering and Systems
- Measurement and Testing Technologies
- Biosystems Engineering
- Robotic Systems

Fields of Research

- Smart Work Systems
- Resource Efficient Production and Logistics
- Convergent Supply Infra-structures

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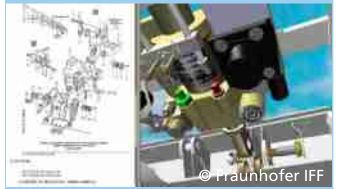
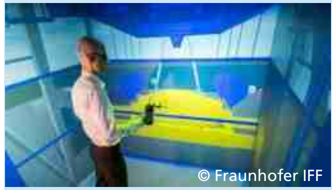
Digital Engineering and Operation

Consistent use of digital data as basis for machine learning applications

Consistent use of digital data along the lifecycle

Design Review	Functional Test	Technical Documentation	Job Preparation	Factory Planning	Education and Training	Operations
						
Engineering, Manufacturing, Assembly, Maintenance	Mechanics, Electronics, Control systems	Visual inter-active catalogs, Electronic manuals	Resource optimi-zation, Work scheduling, Lo-gistics functions	Layout planning, Process planning	Technical staff, Operation and assembly service	Assistant sys-tems, Visual in-teractive repair instructions

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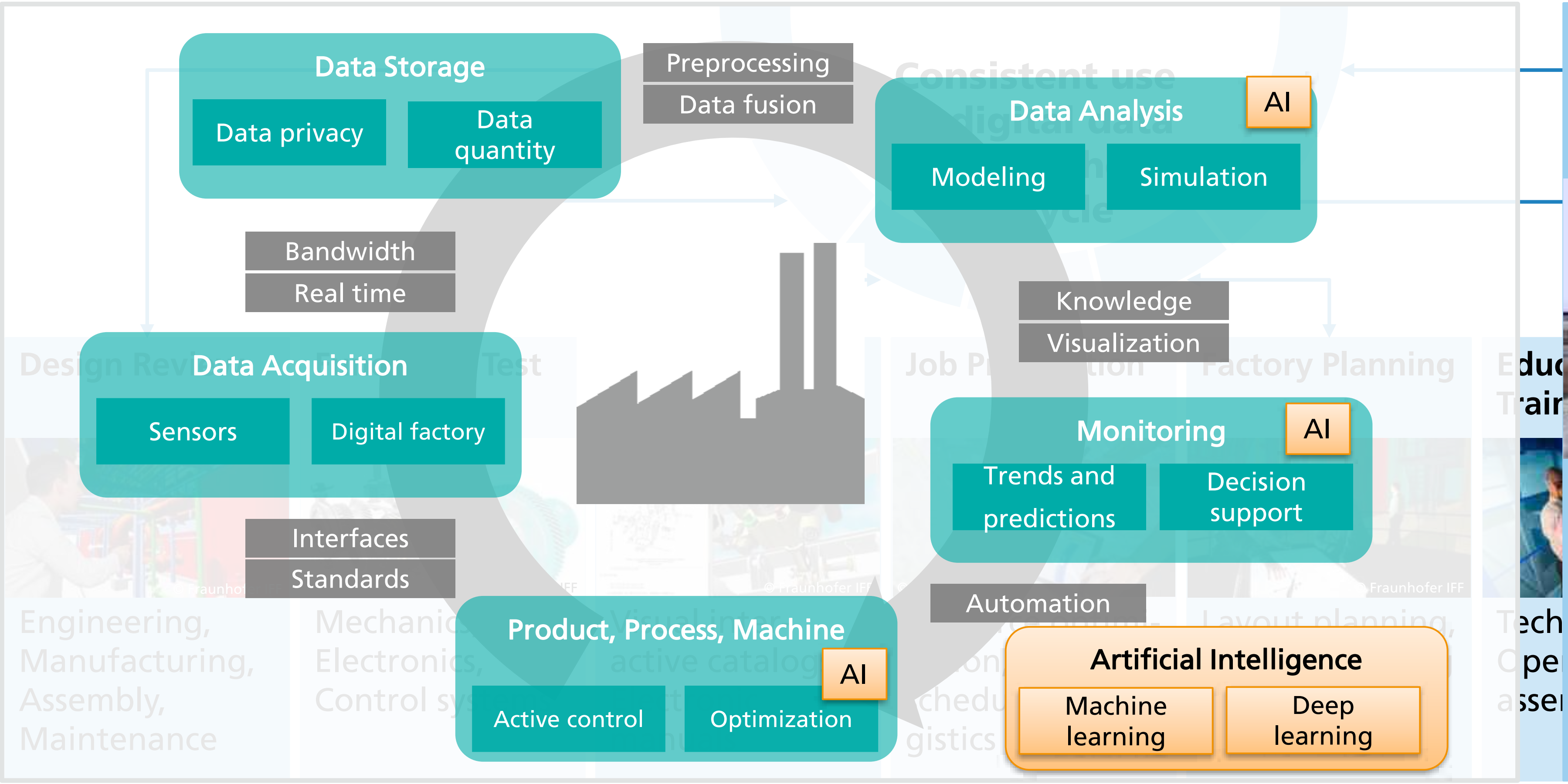
Digital Engineering and Operation

Consistent use of digital data as basis for machine learning applications



Operations

Assistant systems, Visual interactive repair instructions

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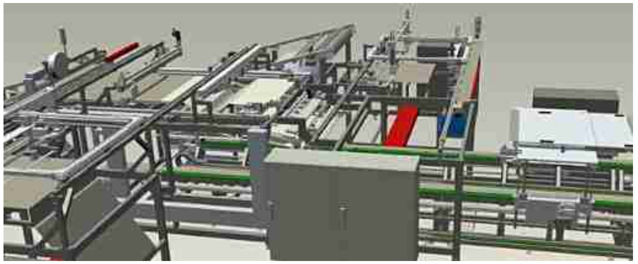
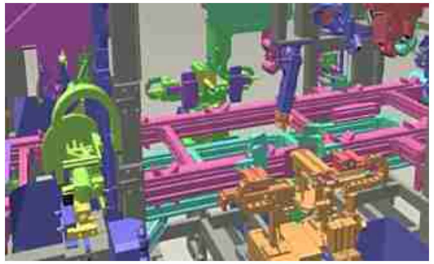
Digital Twin – Cyber-Physical Systems

Integrated and Parallel Product and Manufacturing System Design for LANXESS AG

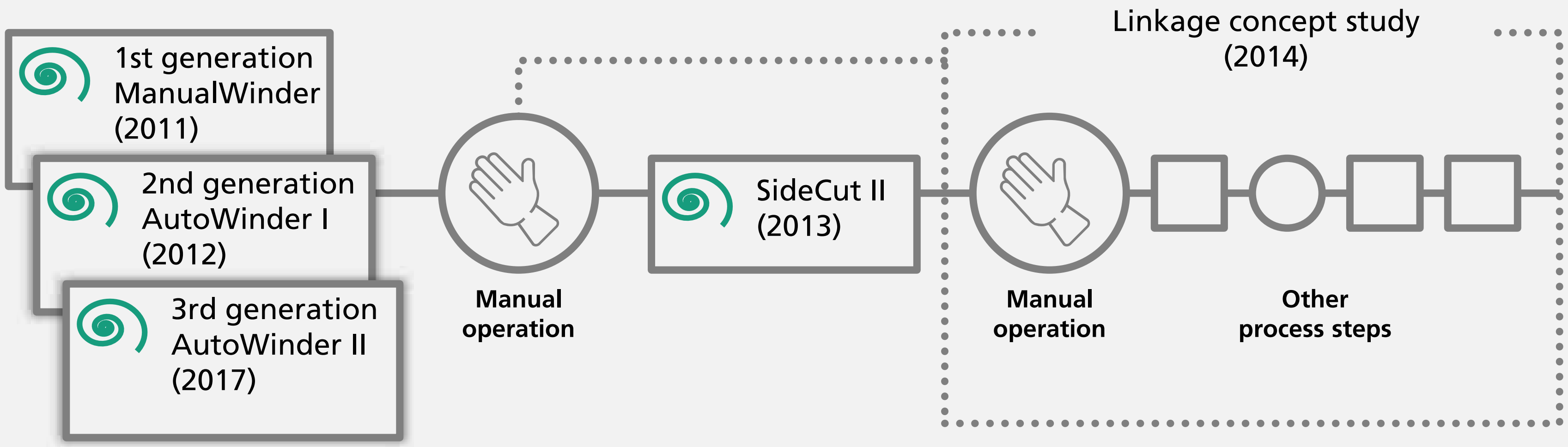




- Use of virtual models and digital tools to plan, develop and prototype the manufacturing system for innovative water filters in parallel to the product development process

Planning and development of several (semi) automated manufacturing systems

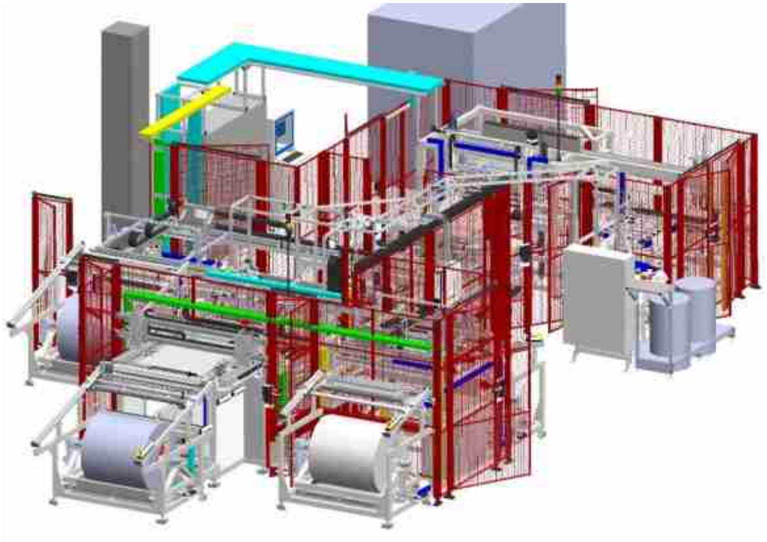
Goal: Fully automated production facility (2020)



- Manufacturing system is in productive use at customer
- Manufacturing system is equipped with intelligent components (sensors, actuators, electrical drives), which provide data
- Data can be used for production run simulations, predictive maintenance, machine learning
- Workers can use data through assistance systems

Fully functioning Cyber-Physical System

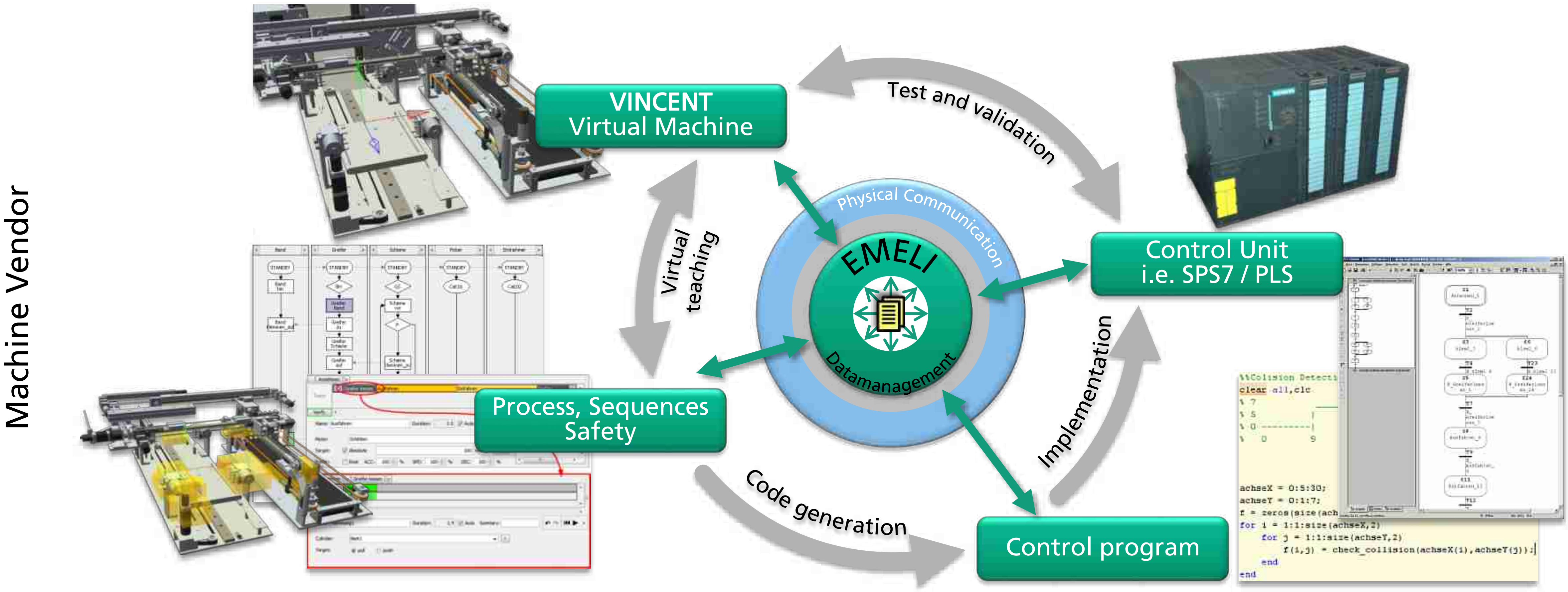
Digital Twin – Cyber-Physical Systems
Working digital twin system in operation



- Real system in operation at customer site

- Virtual system with parallel control visualization

Digital Twin – Cyber-Physical Systems
Digital workflow for virtual prototyping



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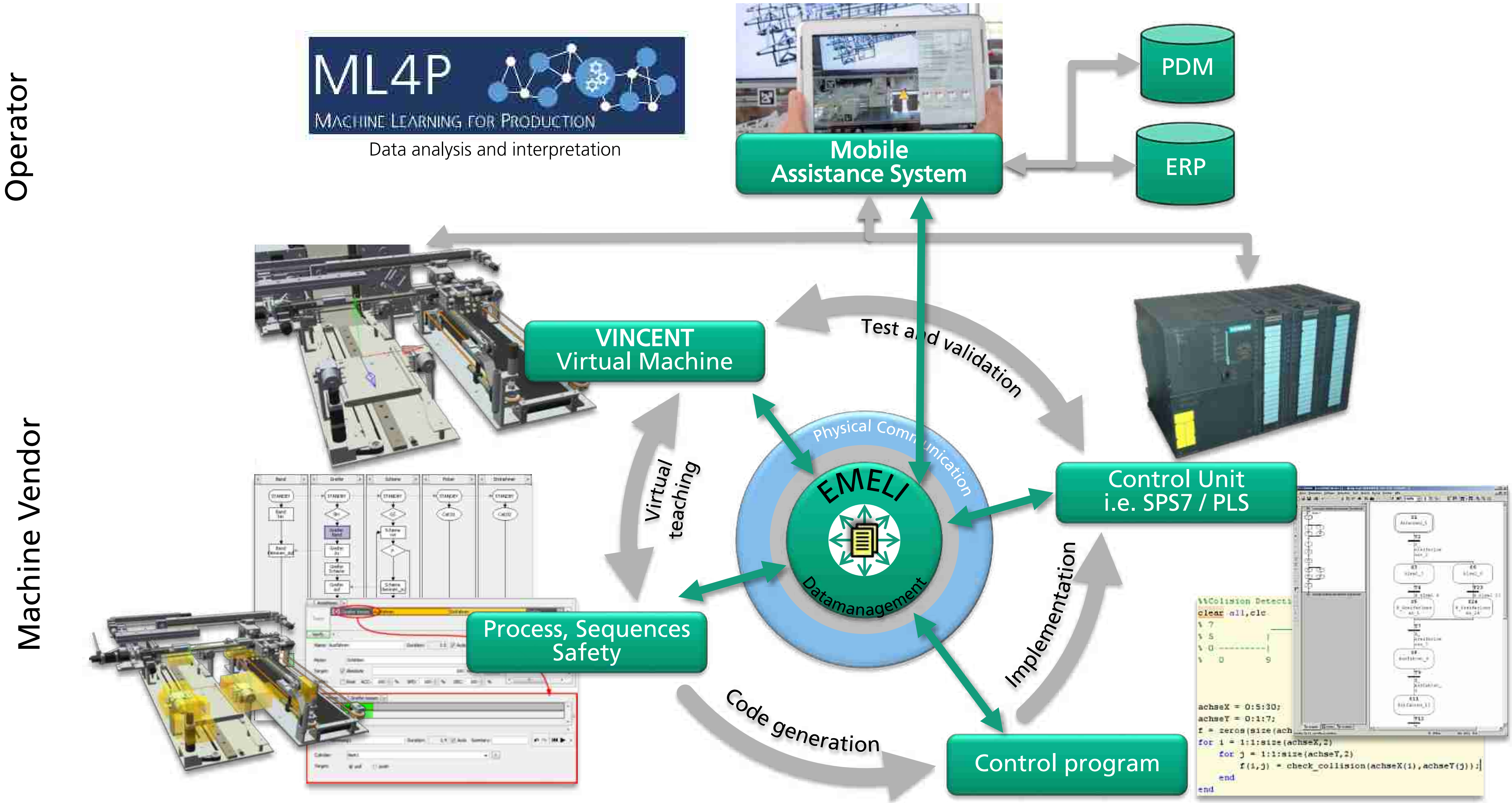

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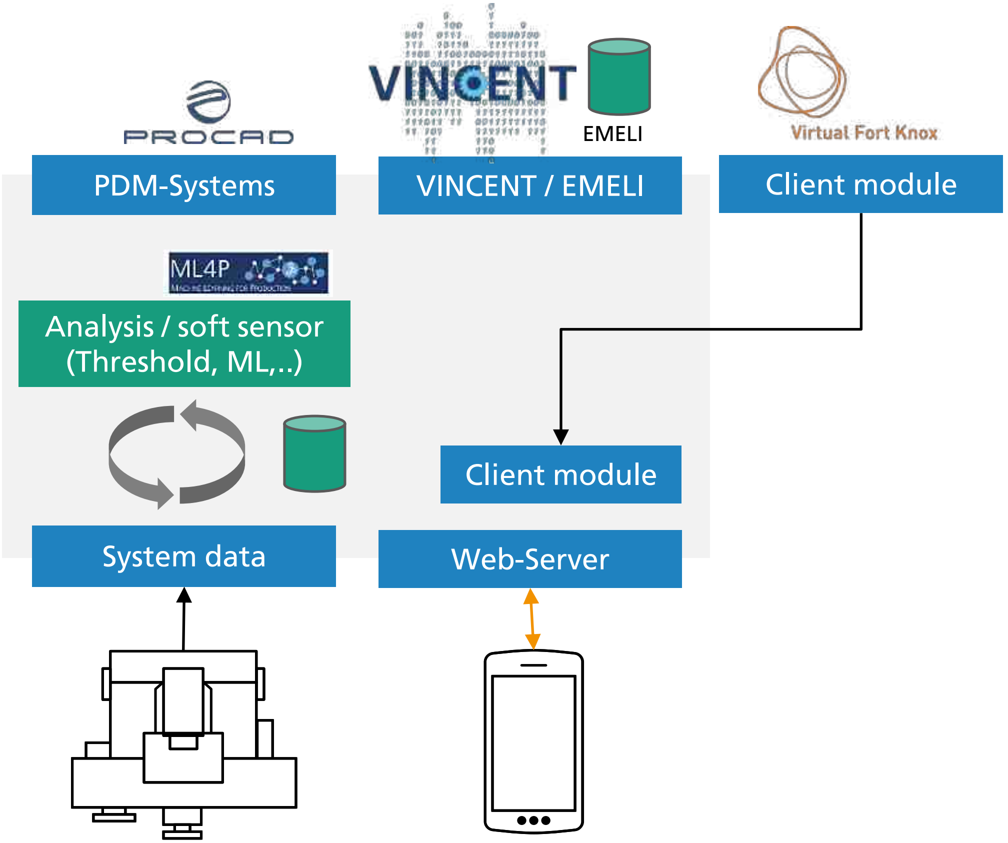
Digital Twin – Cyber-Physical Systems
Assistance systems supported by machine learning

Use case: Considering machine learning applications already in the engineering stage

- Administering and updating of machine learning models in maintenance
- Planning for data interfaces and necessary sensors during the planning stage

Implementation: Scalable, modular framework for assistance systems

- Agent-based method
  - Exchangeable server services for knowledge systems
  - Client modules for customizable information presentation
- No compulsory cloud use, esp. for data and know-how
- Working with system condition states
  - Recording directly in system vicinity
  - Analysis via simple rules-based analysis (similar to Excel, threshold values, etc.)
  - Analysis via online-machine-learning applications



WHAT IF YOU DO NOT HAVE A DIGITAL TWIN LYING AROUND?

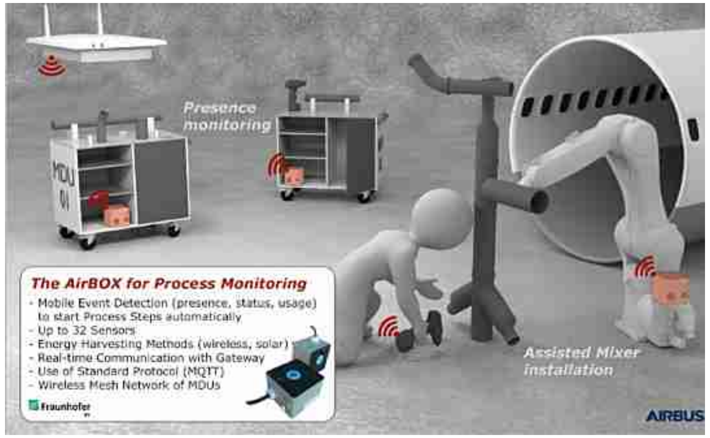
Sensor networks & machine learning
Fraunhofer IFF AirBox

Fraunhofer IFF AirBox to generate process da

- Easy set-up of distributed sensor networks
  - Equipped with six standard industry interfaces
  - Fraunhofer IFF AirBrick also to house sensors
- Already included smart components and logic for mobile event detection (presence, status, usage)
  - Supporting intelligent and hierarchical process monitoring
  - Threshold activation, definition of working bandwidth
  - Autonomous initiation of process steps
- Energy harvesting methods (wireless, solar)
- Wireless real-time provision of process data for machine learning services

Sensor networks & machine learning
Upgrading of existing processes

- Objective: real-time progress monitoring of manual tasks
  - Current state and forecasting for production planner
  - Assembly tips for workers
- Indirect activity monitoring based on machine learning
  - Presence, taking, assembly of parts
  - Use of tools
  - Sensor types: infrared, ultrasound, optical, pressure, temperature, …
- Prototype-Hardware Development: IFF-AirBox
  - Wi-Fi-Sensor Network in production
  - Cloud-based visualization (Partners: e.g. Siemens, T-Systems)



Sensor networks & machine learning

Use case – Installing doors in aircraft fuselage

Problem

- Time-consuming process (1d)
- Installation depends on "micro-properties" of the door and the frame
- Manual logistics
- No progress control

Objective

- Reduction in process time (2h)
- Partial automation
- 3D assistance functionality
- Sensory, digital monitoring
- Real-time progress control

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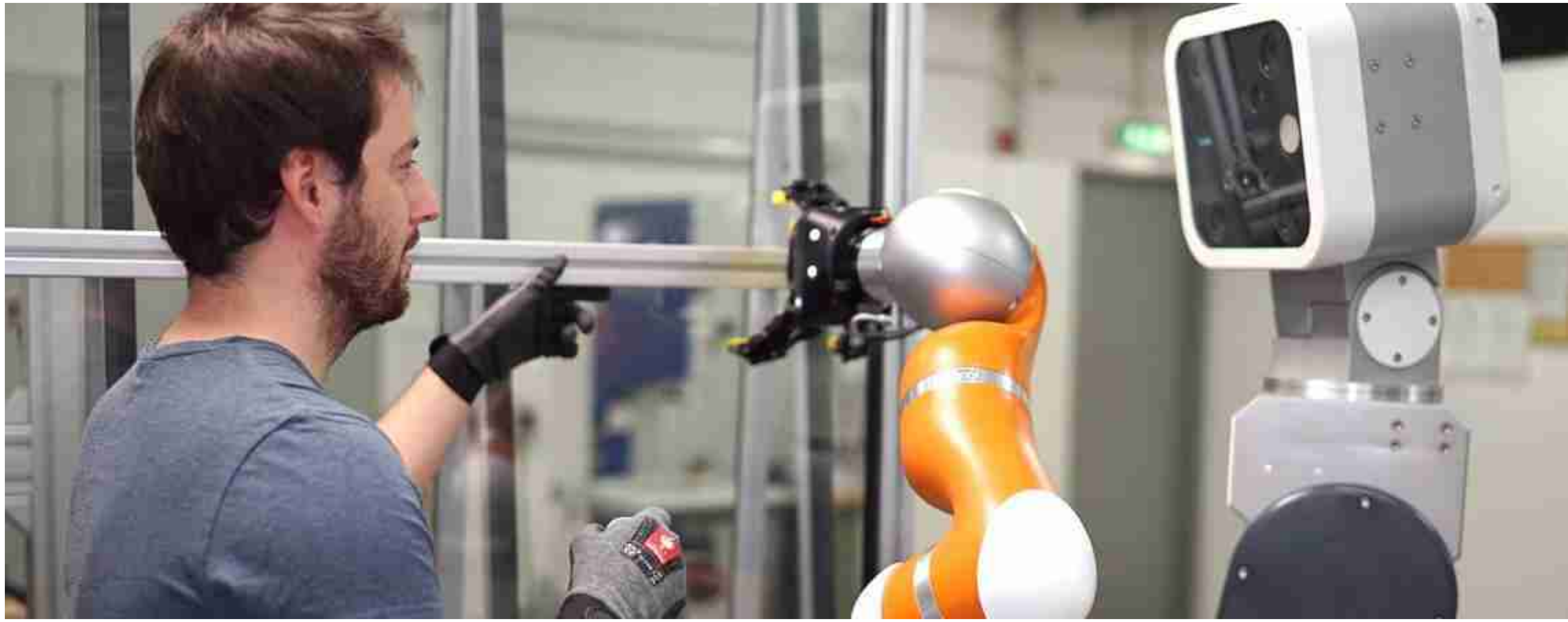
Machine vision & machine learning
Safe human robot collaboration

Objective: Safe collaborative workspaces with interactions between humans and robots

- Mobile robot platform
- Collaboration on joint project
- (in-)direct contact between human and robot
- Robot working following the intention of human
- Safe working environment needs to be ensured



Machine vision & machine learning
Safe human robot collaboration

Objective: Safe collaborative workspaces with interactions between humans and robots

- Supporting machine vision through machine learning
- Algorithms for detection of humans
- Algorithms for detection of individual body parts

WHAT IF YOU DO NOT HAVE FANCY EQUIPMENT?

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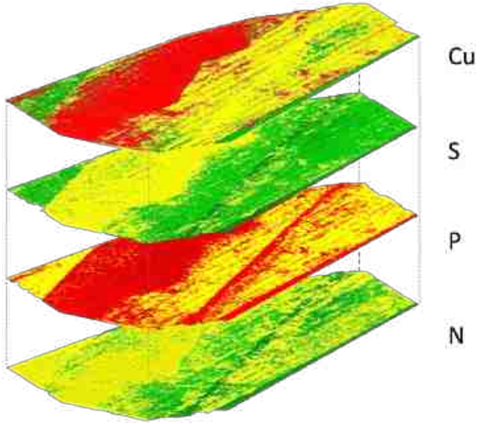
Consumer technology supported by machine learning
Hyperspectral imaging – where we are coming from

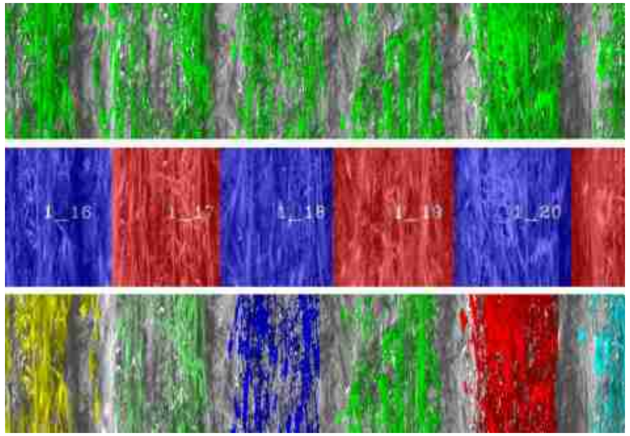
Developing novel applications for hyperspectral imaging, soft sensors and visual analytics for precision farming

- Quantitative monitoring of crop plant *nutrition* beyond nitrogen
- Early (pre-symptomatic) detection of *pathogen* infection and *pest* infestation (biotic stress)
- Quality control of *harvested produce* on-field and during storage
- Assessment of *seed* properties during breeding and quality control in seed production

Fraunhofer IFF Unique Selling Point:

Dedicated mathematical modelling linked to hyperspectral data acquisition

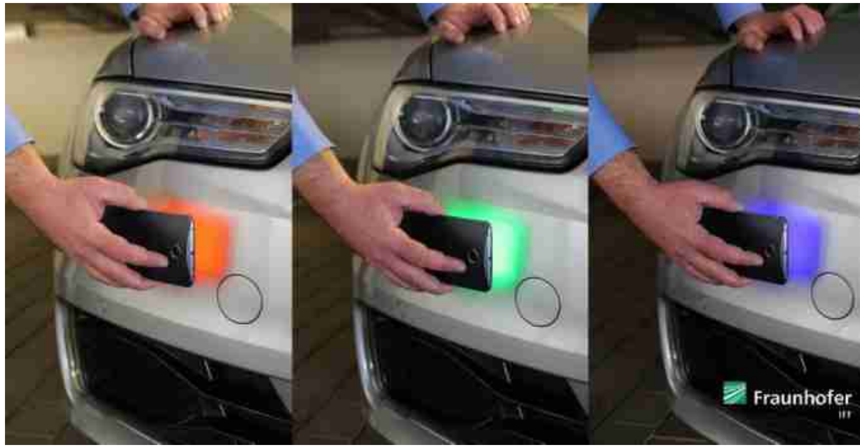




Consumer technology supported by machine learning
Using smartphones as spectral sensor

Objective: Making spectroscopy available for wider applications

- HawkSpex Mobile App uses adjustable illumination of mobile display and front camera to record spectral image
- Using purpose built machine learning models to analyze properties
- Application area:
  - Agriculture and food processing
  - Cosmetics and fashion retail
  - Quality control and product authentication
- New value adding business models



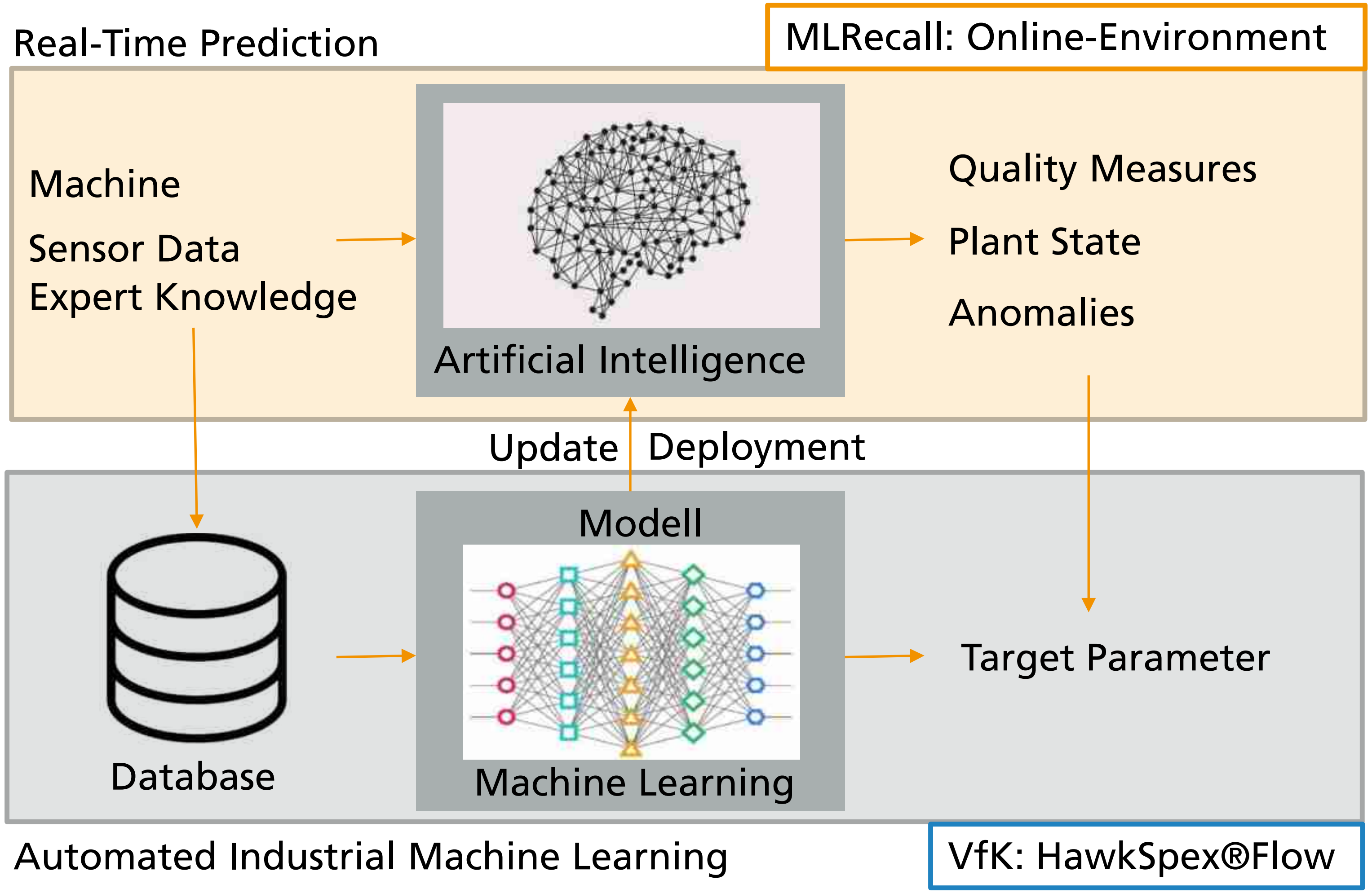
Online machine learning analytics
Cloud-based algorithm development

Objective:

Providing a distributed machine learning environment using cloud-based services on Fraunhofer's Virtual Fort Knox (VFK) research environment

- MLRecall online environment used as client to provide real-time prediction capabilities
- AI in MLRecall based on machine learning models established on VFK cloud environment running HawkSpex®Flow

Research Virtual Fort Knox



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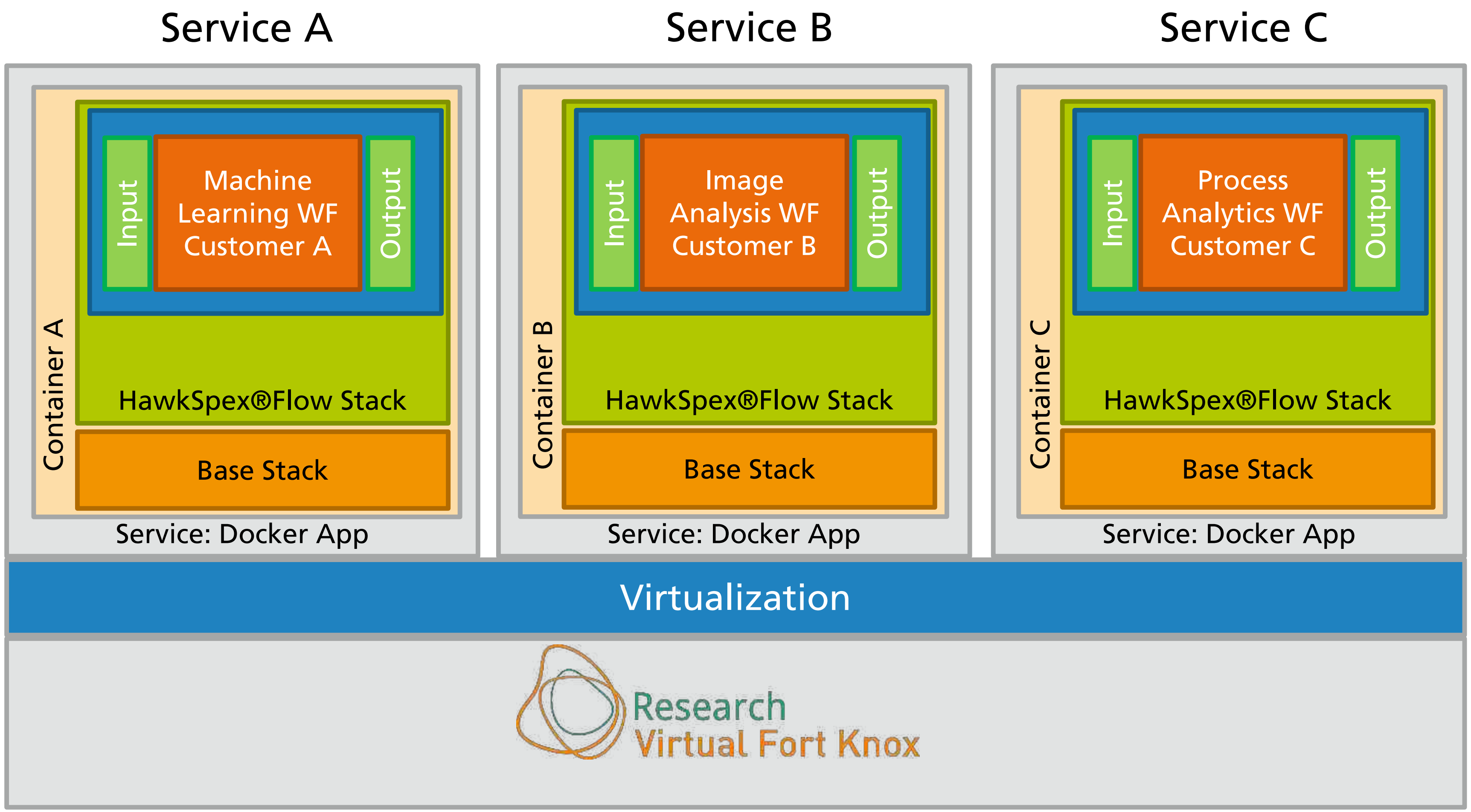
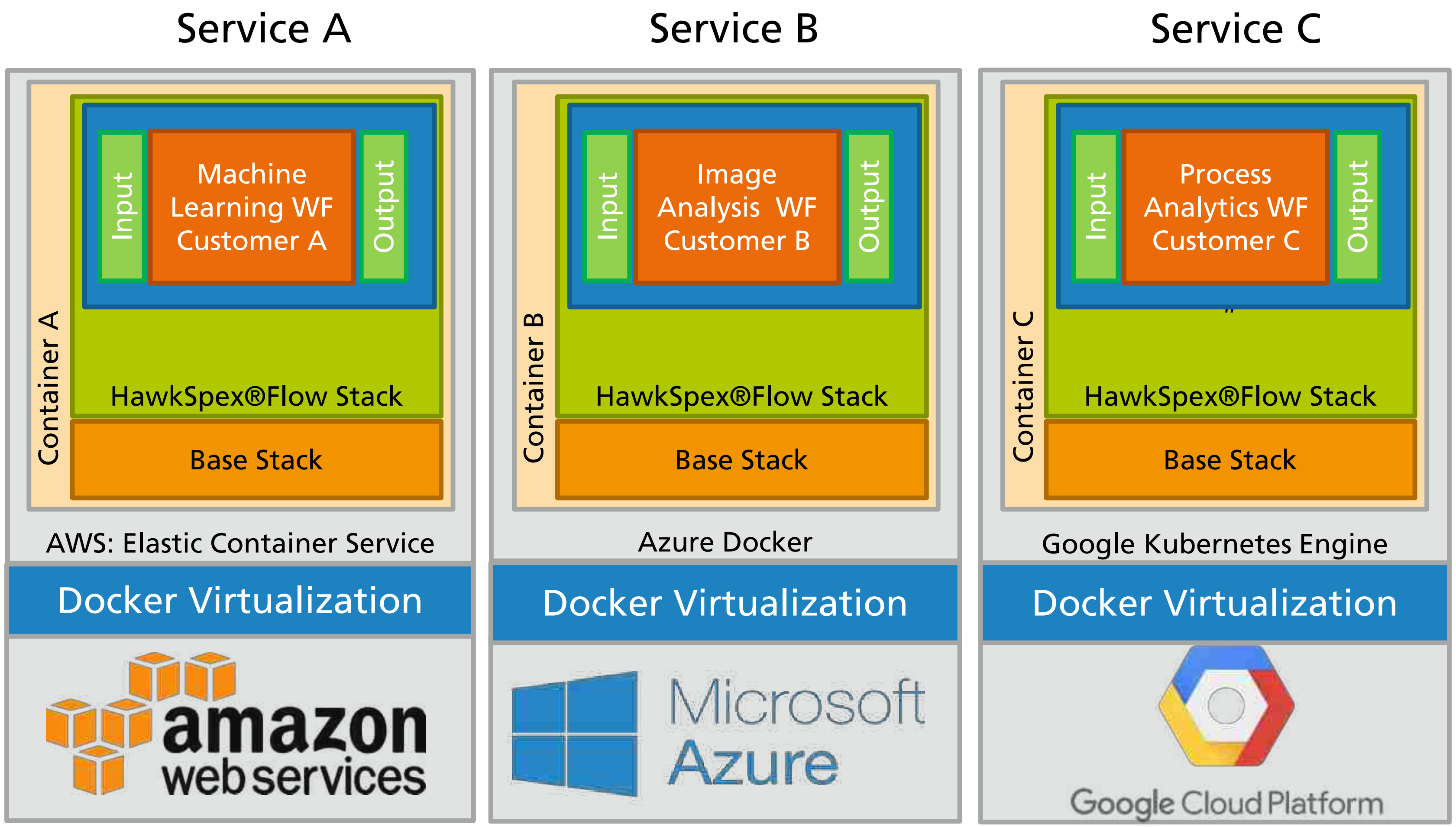
Online machine learning analytics
HawkSpex®Flow – Development on Virtual Fort Knox



Online machine learning analytics
HawkSpex®Flow – Develop with us, Run Anywhere



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WHAT IF I DO NOT HAVE ENOUGH DATA?

Machine learning & insufficient data
Combining hard and soft information

Framework conditions:

- Process industries with continuous production
- Relative small numbers of incidents

Objective:

- Prediction of clogging of a two-fluid injection nozzle

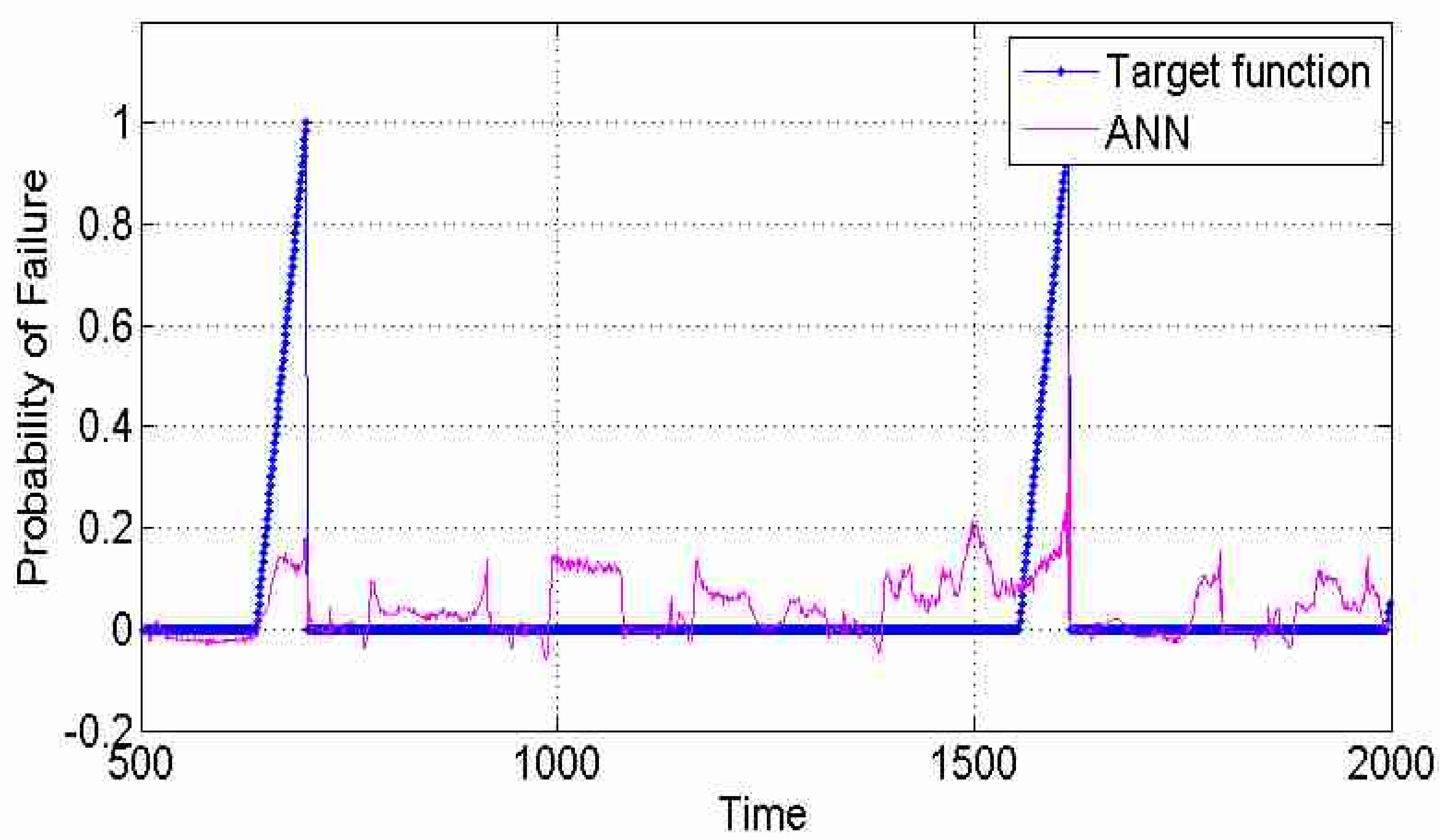
Data:

- 14 instances of clogging
- 1 Hz data acquisition rate
- Pressures und flow rates of compressed air and liquid

Machine learning & insufficient data
Putting machine learning to use on small data sets

Using historical/available data to train an artificial neural network (ANN) to predict failure events

- Insufficient data on failures did not result in high enough predictive power for the AI
- Clogging events could be identified in the data but could not be distinguished from noise
- A model purely trained on historical data was not feasible



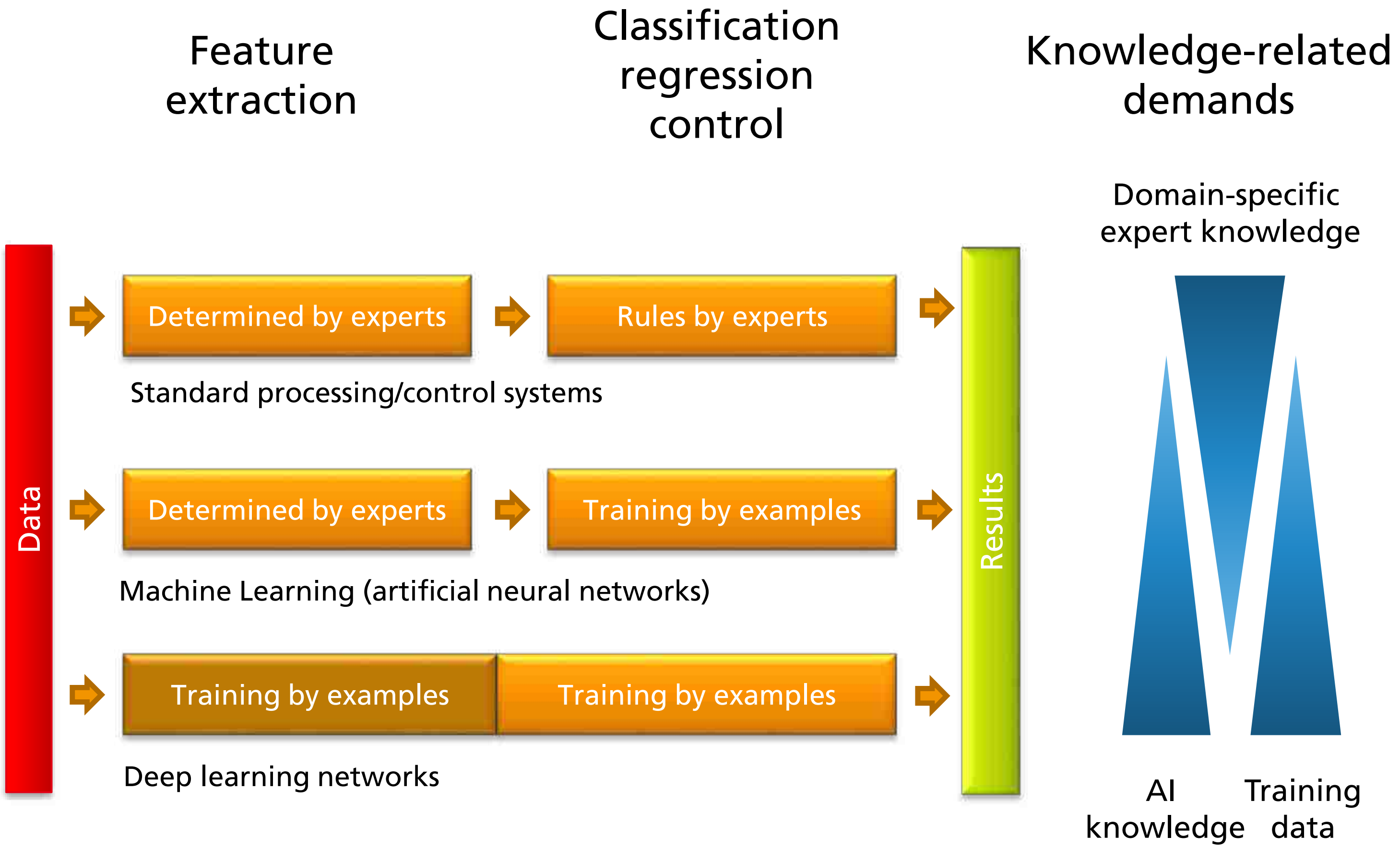
Machine learning & insufficient data

Combining hard and soft information

You have to know when machine learning is a viable way forward

Data is key but expert knowledge should not be underestimated

- Expertise in special fields turns into knowledge in AI
- AI / machine learning: Higher dimensional and complex data
- Deep learning needs masses of data,



Machine learning & insufficient data

Predictive maintenance with humans in the loop

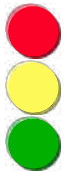
Source:
http://de.web.img3.acsta.net/r_1920_1080/medias/nmedia/18/35/24/10/18959188.jpg

- Fraunhofer IFF has long history of predictive maintenance projects
- Challenge “before Industrie 4.0” was how to generate the necessary data
- Maintenance staff has first-hand knowledge of and experience with a system, its operational- failure characteristics
- Exploiting expert-knowledge to define maintenance rules

Data and information collection → Processing and saving of measurement values → Interpretation, Decision and Action

↑ seeing, hearing, feeling, smelling, tasting appreciation (5 human senses)

↑
- Knowledge
- Experience
- Thinking + Assistance

↑ 

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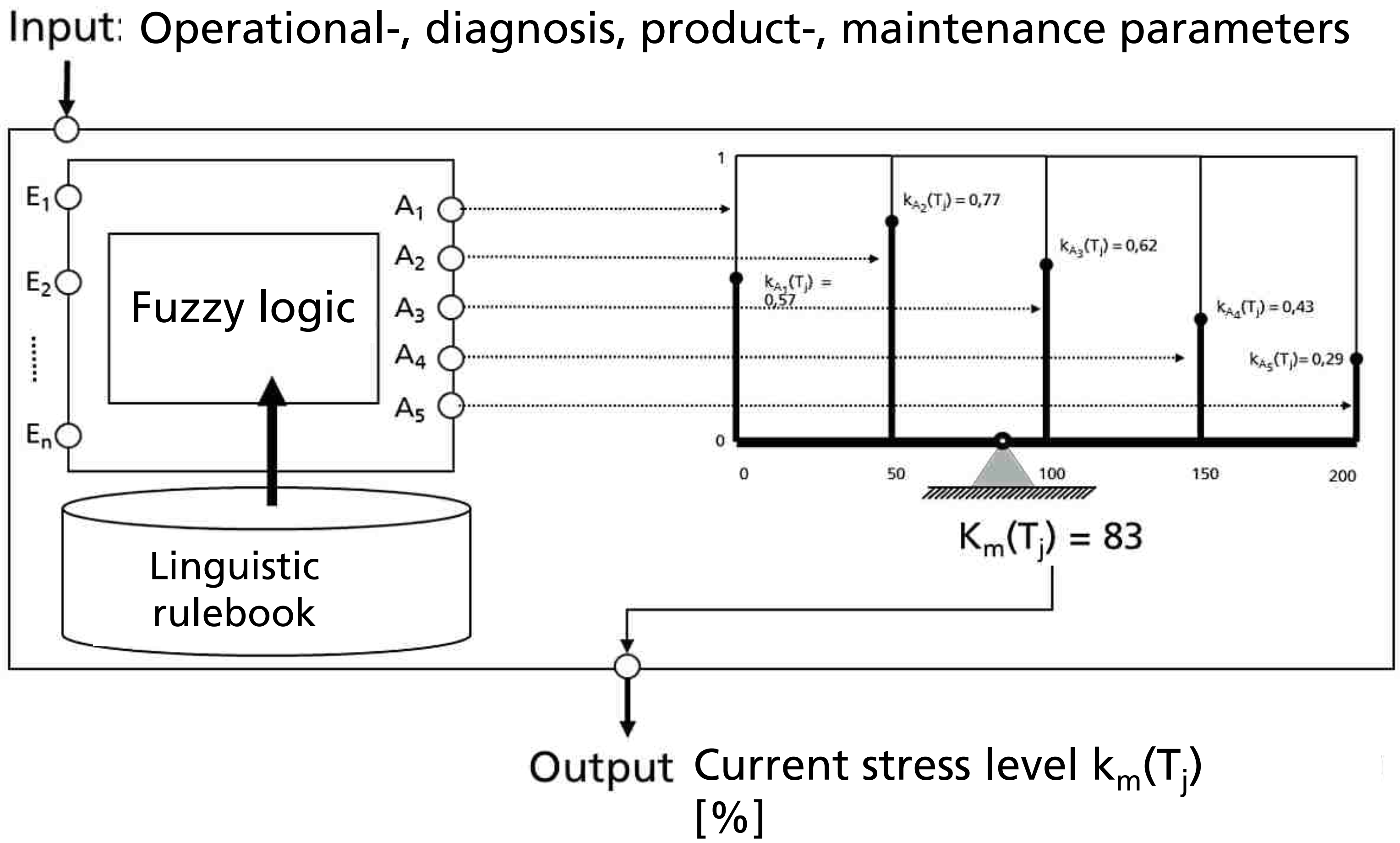
Machine learning & insufficient data
Predictive maintenance with humans in the loop

- **Examples for experience knowledge**
  - “The machine should run for at least eight hours a week.”
  - “We have to change the motor approximately every five years.”
  - “We need to quickly exchange the bearing when the motor gets loud.”
- **Challenge**
  - Quantification of values such as “at least“, “approximately”, “loud”, “quickly”, etc.
  - Subjective assessments of different people with own/different experiences
- **Fraunhofer IFF approach: Fuzzy-Logic**
  - Linguistic rules IF (*Sound* = loud) THEN (*Stress* = *high*)
  - Calculations for deductions and collecting multiples rules for a combined assessment

Machine learning & insufficient data

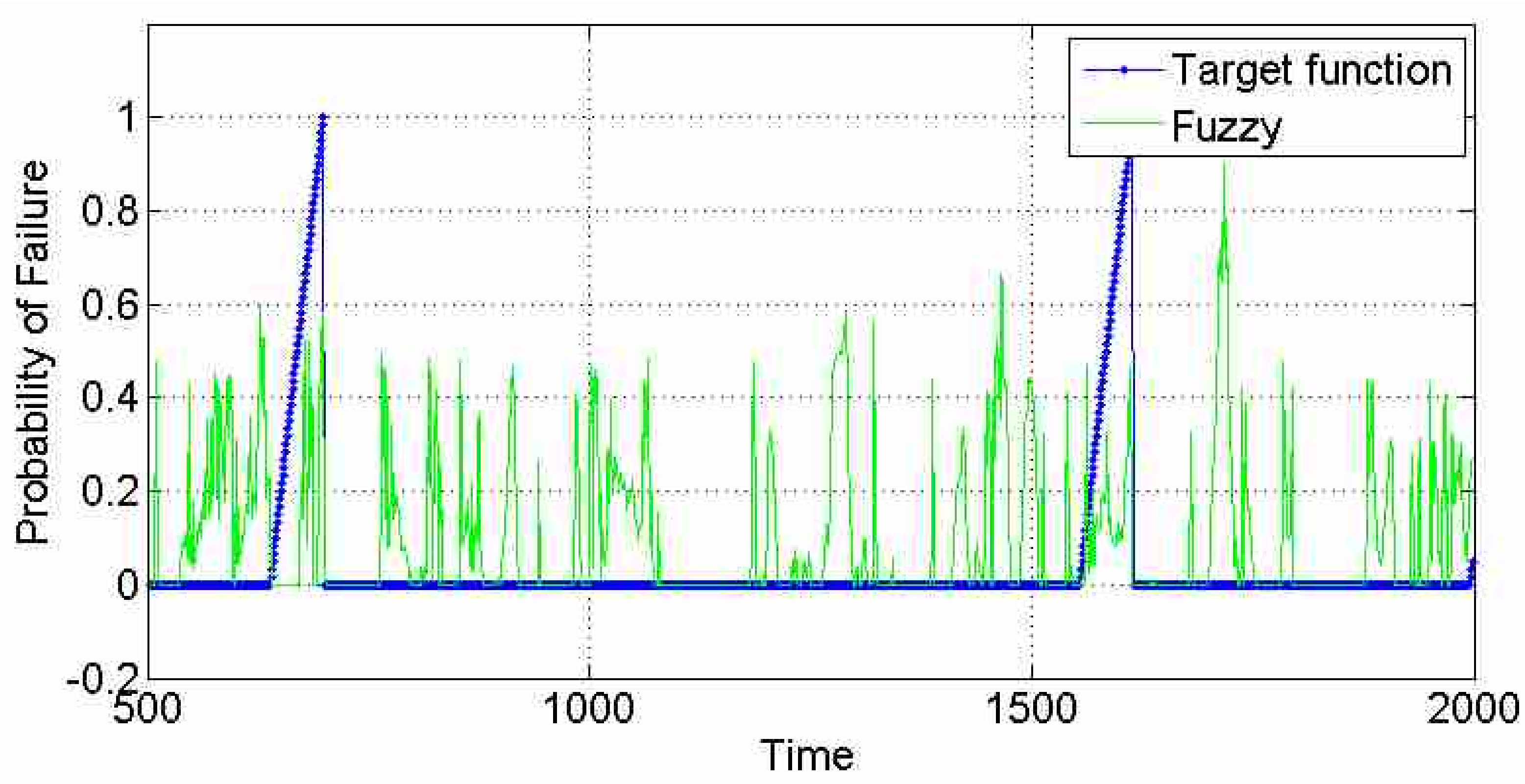
Predictive maintenance with humans in the loop



Machine learning & insufficient data
Putting the Fuzzy logic to use

Using the operator's experience knowledge and a fuzzy logic approach to predict failure events

- Fuzzy logic created to many failure predictions / too much noise to allow for any predictive power



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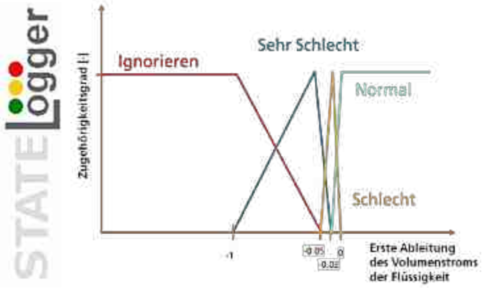
Machine learning & insufficient data

Combining machine learning and fuzzy logic

Input data

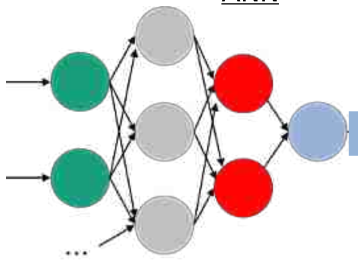
Operational data & derivations

- Dispersion air pressure [bar]
- Volume current of liquid [l/min]
- Liquid pressure [bar]
- …

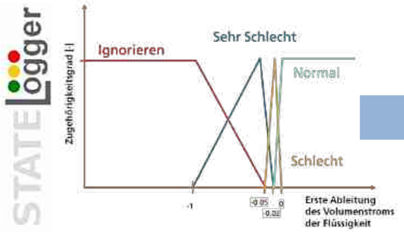


Assessment tool

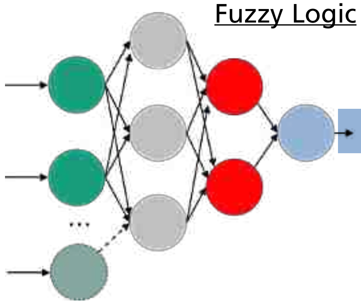
ANN



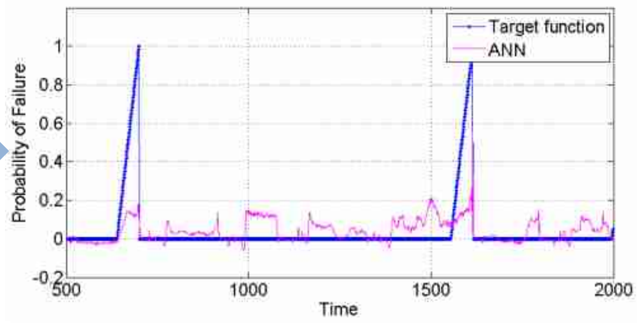
Fuzzy Logic

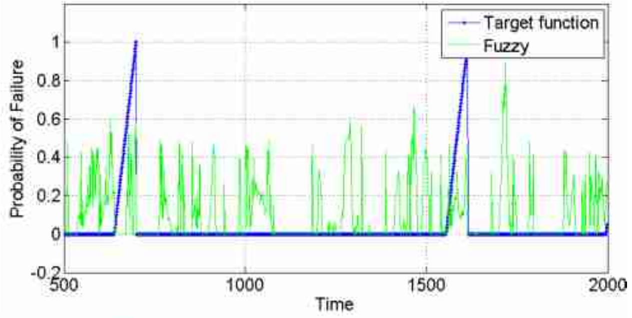


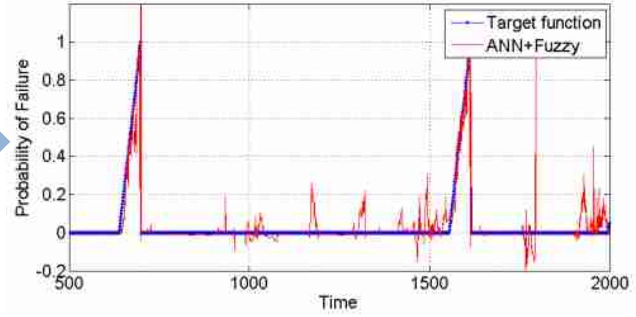
ANN with Fuzzy Logic



Failure probability







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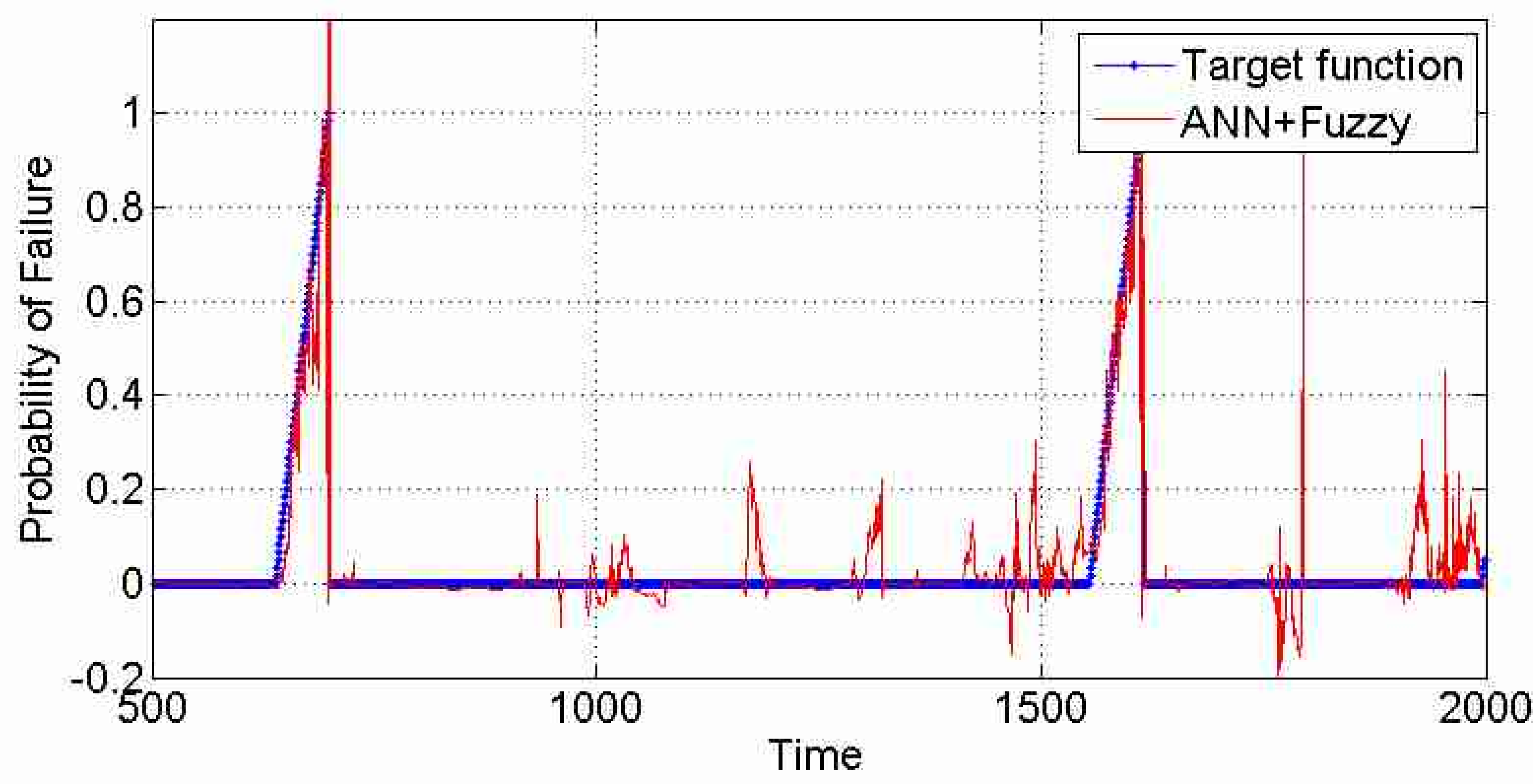
Machine learning & insufficient data
Fuzzy logic supported machine learning

Using a combination of the fuzzy logic approach and historical data in an artificial neural network (ANN) to predict failure events

- Prediction algorithm provides a nearly perfect fit to the data
- Failure events are clearly identifiable
- Additional spikes can be discounted as non-relevant as rise-pattern does not correspond to data



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Fraunhofer Institute for Factory Operation and Automation IFF	Dr. Uwe Knauer	Christian Blobner
Sandtorstr. 22 39106 Magdeburg	Biosystems Engineering Tel.: +49 391 4090 135	Institute Management Tel.: +49 391 4090 371
www.iff.fraunhofer.de	uwe.knauer@iff.Fraunhofer.de	Christian.Blobner@iff.fraunhofer.de

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