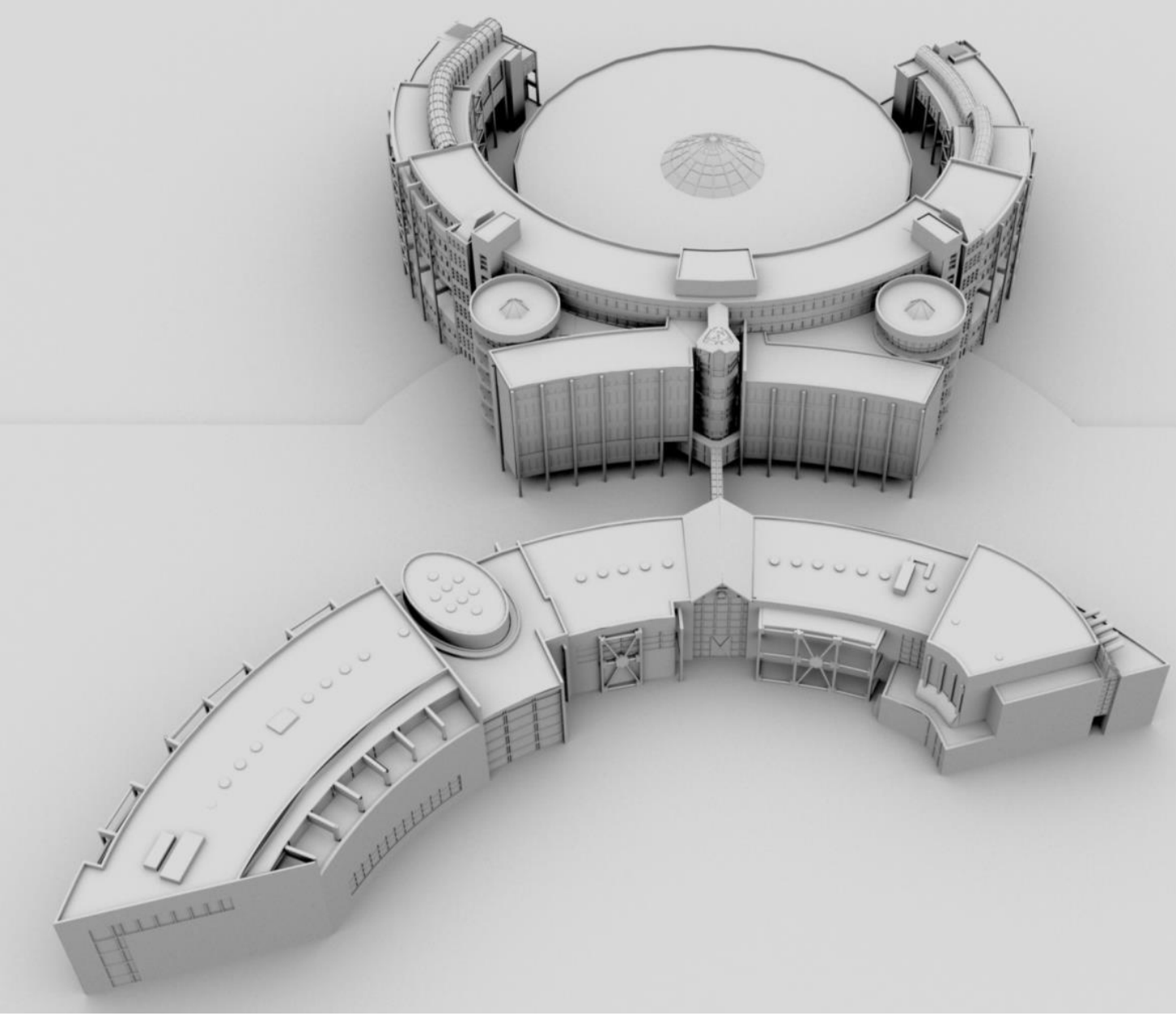

June 14th 2022

Smart Maintenance – Digital networking as a holistic solution

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OUTLINE

- Fraunhofer IPK
- Predictive Maintenance in Industrie 4.0
- Smart Maintenance Enabled by Intelligent Manufacturing Technologies
- Enabling Elements for Smart Maintenance
- Smart Maintenance Architecture
- Context Sensitive Assistance Systems
- Condition Monitoring & Prediction of Failures
- Roadmap to Smart Maintenance

Production Technology Center Berlin

Research for industrial production

Production Technology Center Berlin

Application-oriented and basic research

… for the entire spectrum of industrial usage:

- Managing companies
- Developing products
- Manufacturing products with innovative manufacturing technologies, machine tools and tools
- Automating processes

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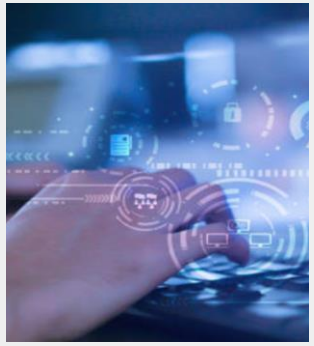
Fraunhofer IPK: Productions Systems

Your research partner for the digitally integrated production

Digital Transformation

From technology-oriented to application-driven solutions

So far: technology focus



Digitalization Industrie 4.0

- IoT
- CPS
- Smart devices
- Cloud
- Apps
- …

Investments / Innovation / Focus

- IT infrastructure
- Automation solution
- Plant and equipment technology
- Software

In future: application focus

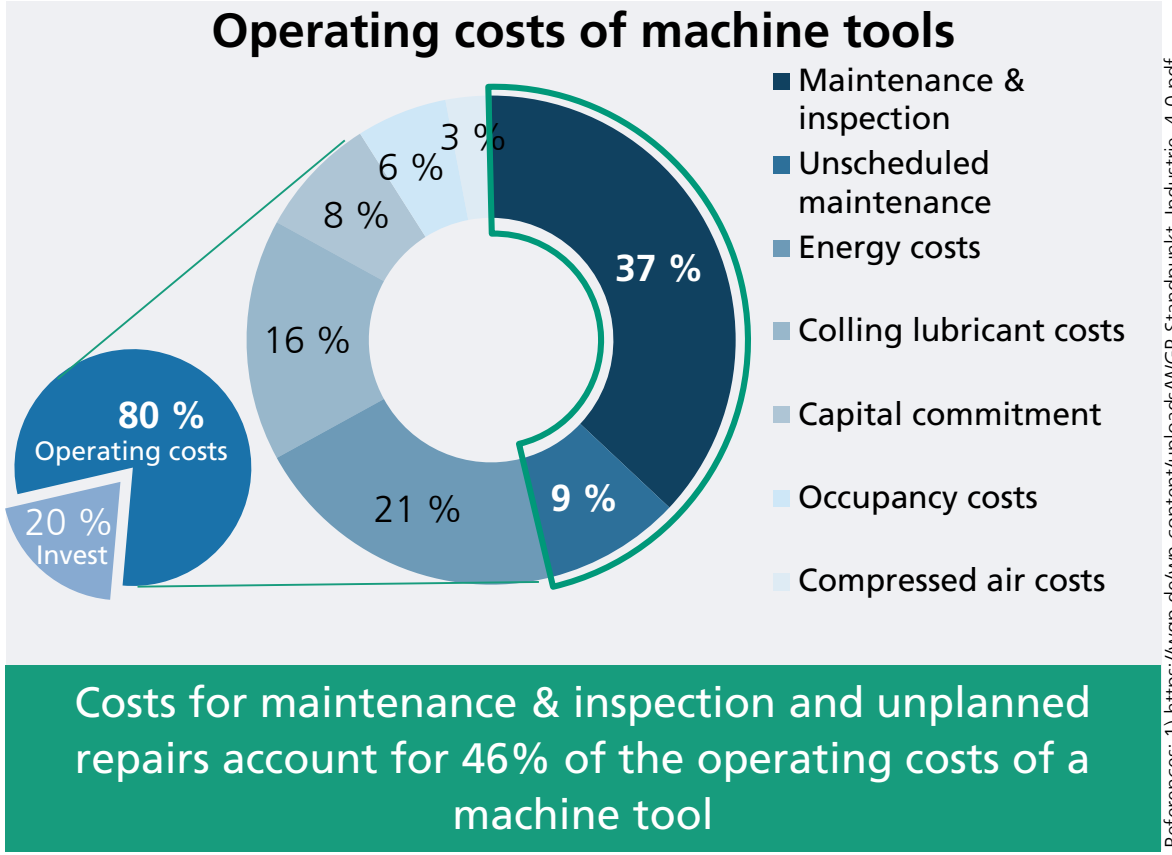
Digitally Integrated Value Creation

- Corporate and business processes
- Development and engineering processes
- Intelligent adaptive production systems
- High-performance production

Predictive Maintenance in Industrie 4.0

Increasing profitability through data-driven value creation

- **82% of companies experienced** at least one and an average of 2 **unplanned downtimes** in the past three years.
- For **72% of companies** surveyed, **zero unplanned downtime is the #1 priority** or at least a high priority.
- Up to **220,000 € / h** cost of equipment **downtime**
- 70% of manufacturing companies surveyed do not know exactly what the condition of their assets
- **Predictive maintenance as a key factor** in the manufacturing industry
- **Cost allocation over the entire service life** for the operation of machine tools



Costs for maintenance & inspection and unplanned repairs account for 46% of the operating costs of a machine tool

References: 1) https://wgp.de/wp-content/uploads/WGP-Standpunkt_Industrie_4-0.pdf
2) https://www.adtance.com/de/blog/2020/die-grossen-verluste-durch-ausfallzeiten-in-produktionsbetrieben
3) https://www.aisight.de/blog/vier-moglichkeiten-um-die-lebenszykluskosten-einer-zentrifugalpumpe-zu-reduzieren/amp/

Smart Maintenance Enabled
by Intelligent Manufacturing Technologies

INTEGRATED SMART MAINTENANCE CONCEPT FOR MACHINE TOOLS

https://www.youtube.com/watch?v=UopjwMvwvME

IoT

Development of IoT architectures and pipelines

Analysis of variable cyber-physical systems and connectivity of sensors in existing components

Solution:

- Design of data pipelines for analysis
- Development of virtual representations of components (digital twins) using asset administration shells
- Combination of heterogeneous data sources

Added Value:

- Basis for the development of **data-driven business models**
- **Standardized access to data**
- Preparation for **use-dependent analysis of data**

Smart Maintenance

Intelligent degradation, plant and process monitoring

IoT-based networking of systems and cloud services with adaptive sensor networks for condition monitoring to support maintenance.

Solution:

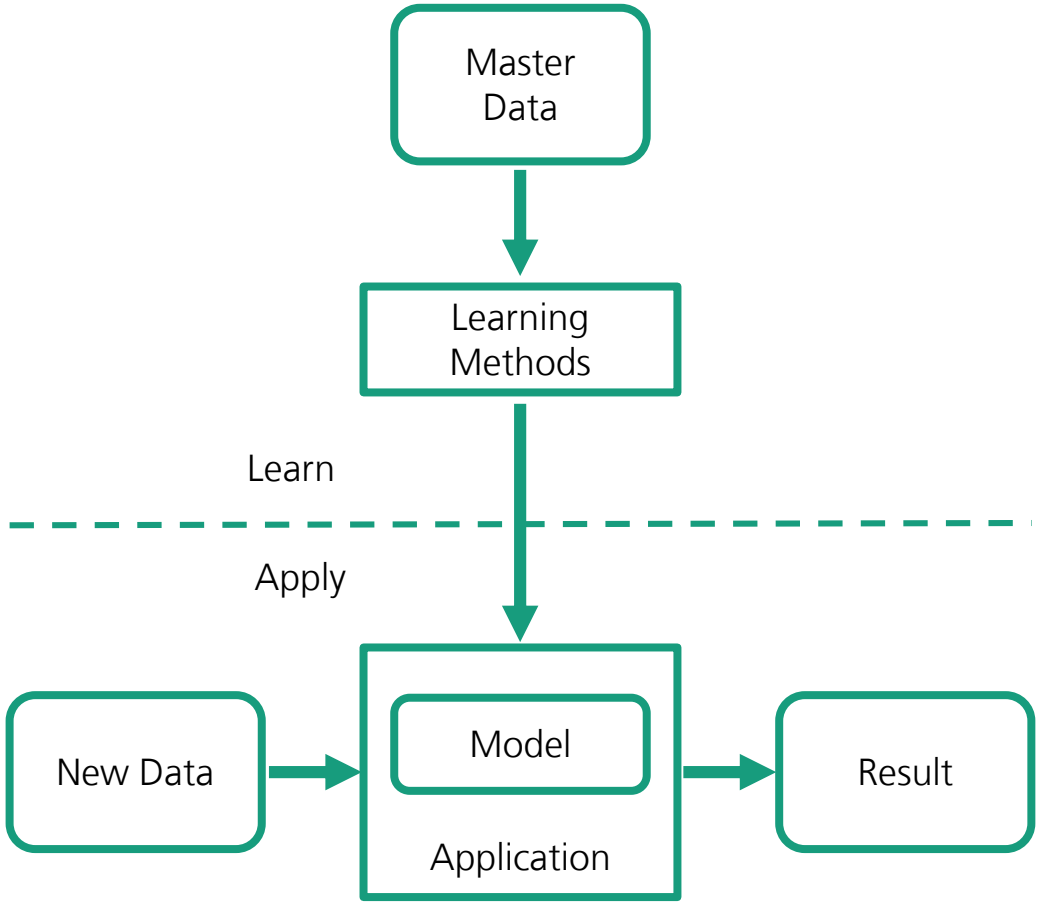
- Real-time evaluation of processes
- Context-sensitive process support through mobile assistance systems
- Integration of historical data from machine and components
- Development of application-related digital twins

Added Value:

- **Reliability** through avoidance of unplanned downtimes
- **Increased efficiency** of maintenance measures
- **Data transparency** through traceability and documentation
- **Cost-effective I4.0 retrofit** for existing plants

Machine Learning – Principle

- Creating the desired behavior of a computer system without explicit modeling or programming of an algorithm
- Learning and training using examples
- Feedback learning for continuous improvement
- Decision support, recommendations
- Tasks
  - Classifying for Characteristic Distinctions
  - Anomaly detection
  - Predictions
  - Adapt behaviour and strategy



Model Generation using Feedback Learning

Machine Learning – Principle

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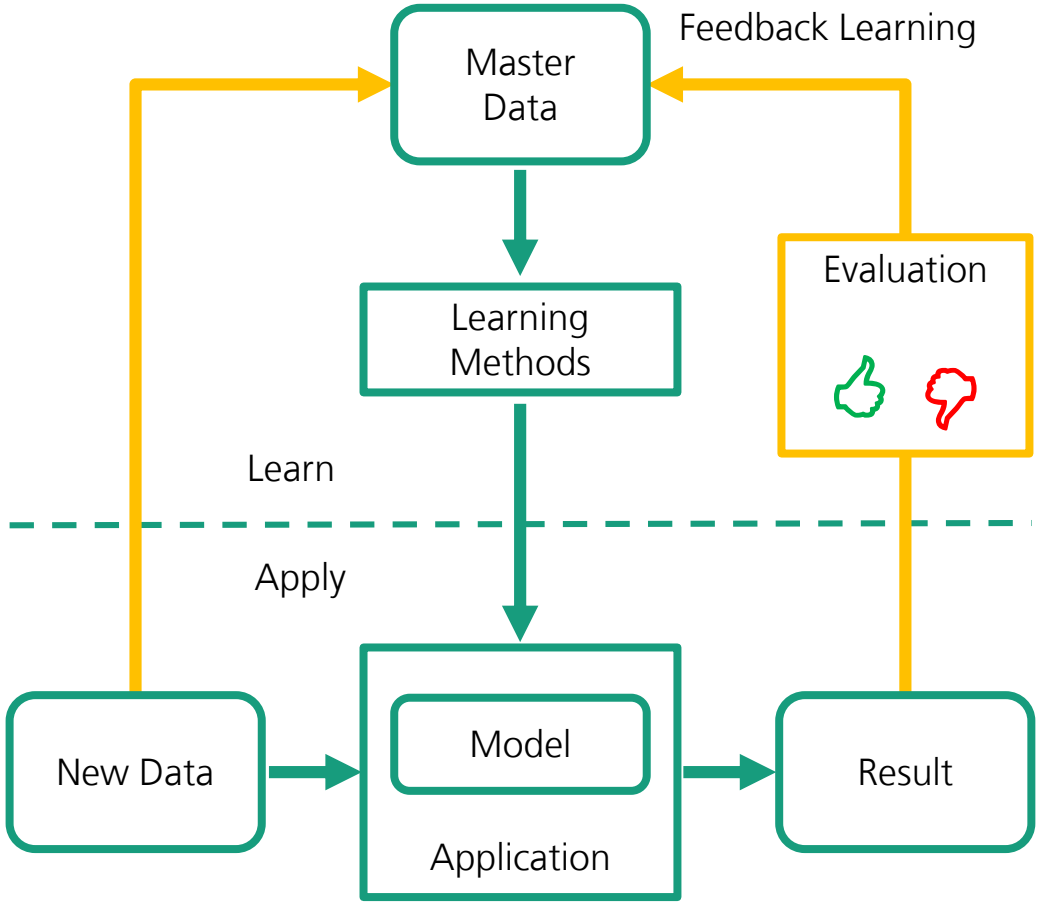
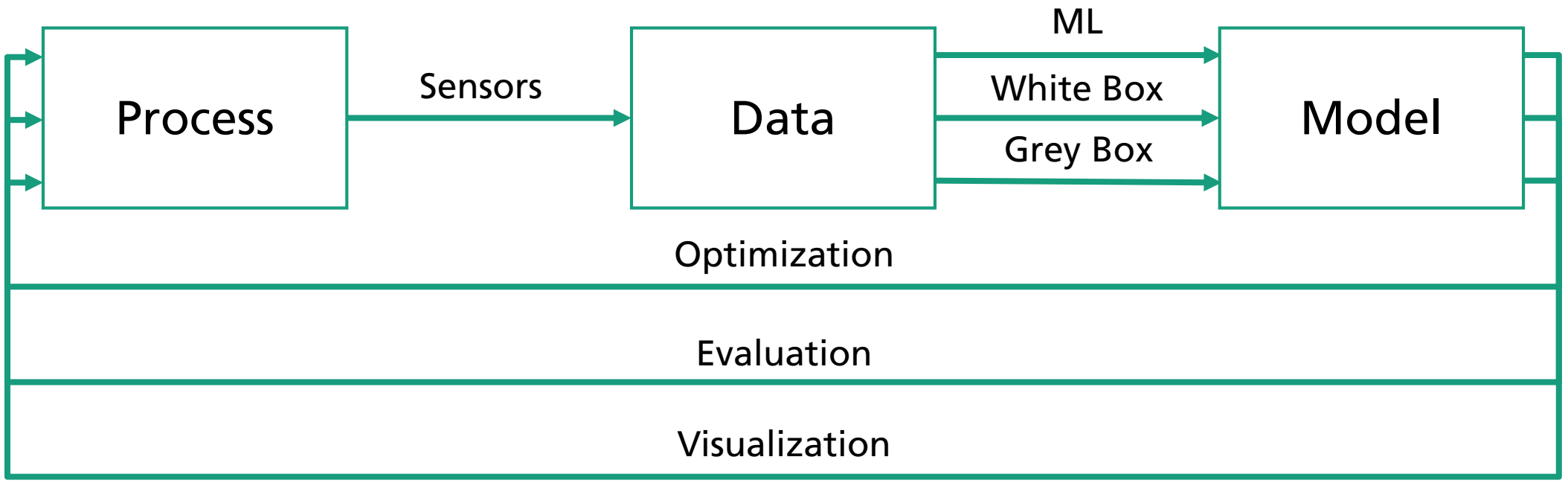


Model Generation using Feedback Learning

Process-driven AI approach for Production Industry

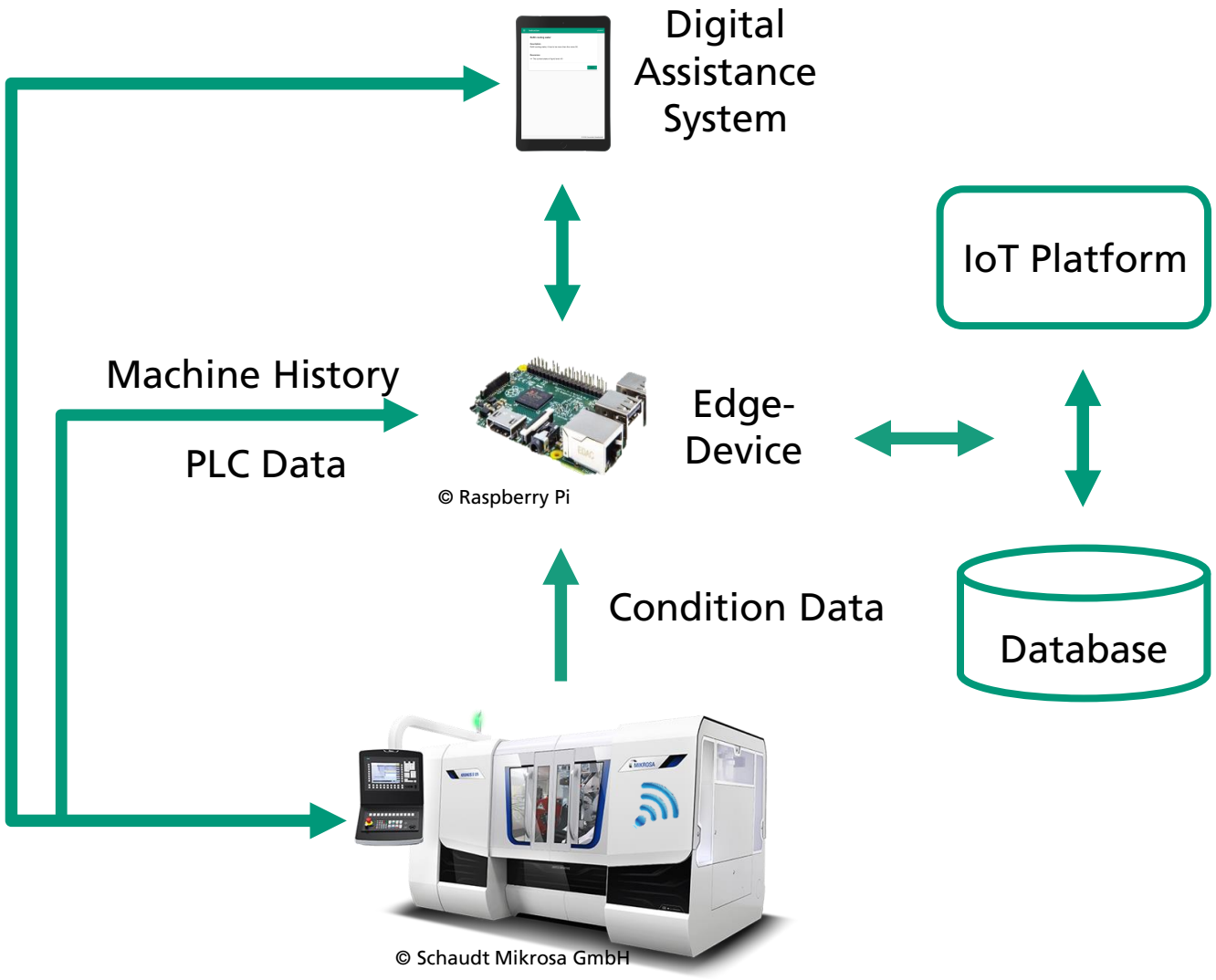


Source: https://wgp.de/wp-content/uploads/WGP-Standpunkt_KI-final_20190906-2.pdf

Smart Maintenance System

Condition Monitoring

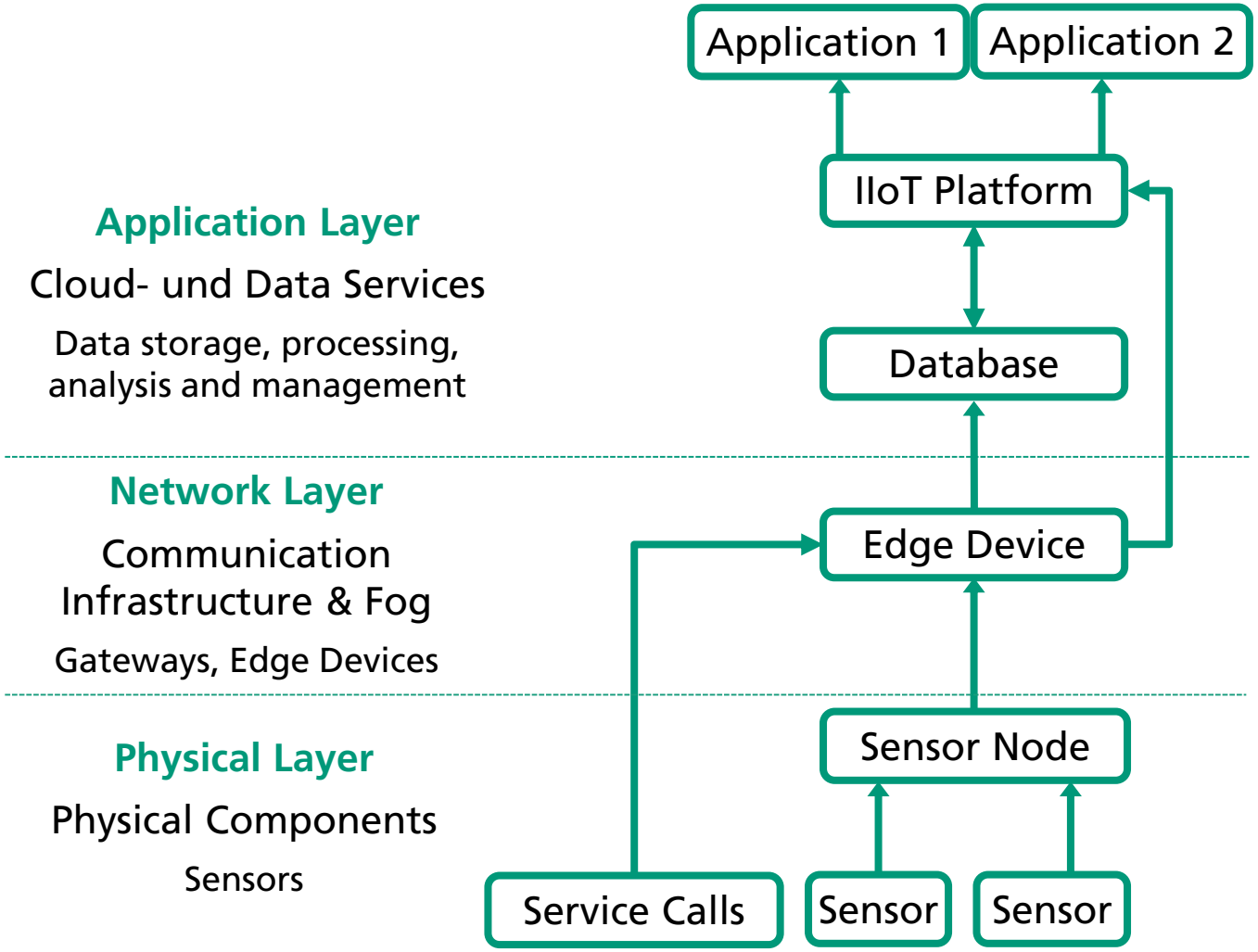
- Data from interactive and context-sensitive assistance systems for mobile devices during maintenance operations
- Data linkage from product development and use, including service
- Use of historical data as the basis for remaining useful life (RUL) predictions



Source: Uhlmann, E.; Polte, J.; Koutrakis, N.-S.: Holistic Concept Towards a Reference Architecture Model for Predictive Maintenance. In: Procedia CIRP, Vol. 104, 2021, S. 1430-1433.

Three-layer IIoT system architecture

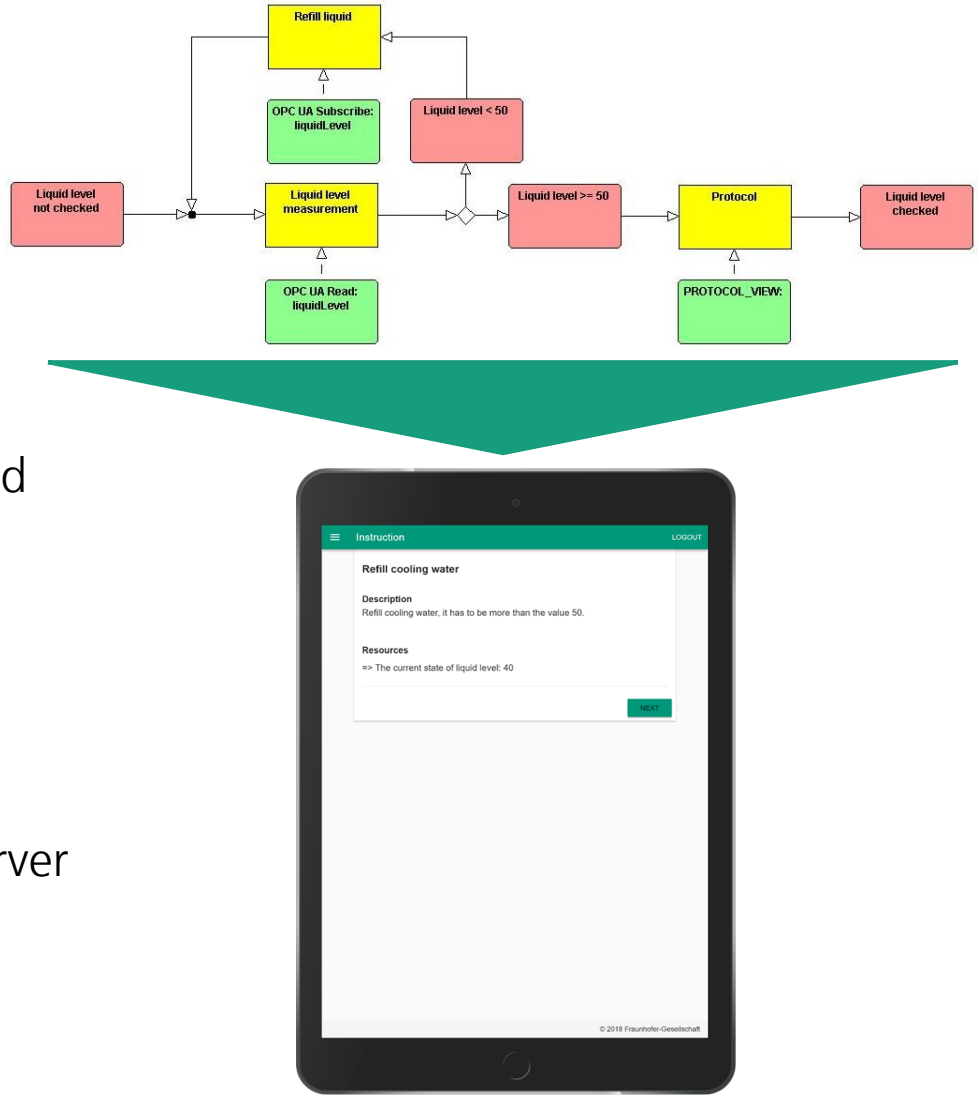
- Application Layer
  - Cloud Services
  - Data Services
- Network Layer
  - Communication Infrastructure
  - Fog
- Physical Layer
  - Physical Components



Source: Uhlmann, E.; Polte, J.; Koutrakis, N.-S.: Holistic Concept Towards a Reference Architecture Model for Predictive Maintenance. In: Procedia CIRP, Vol. 104, 2021, S. 1430-1433.

Digital Maintenance Assistance

- Context sensitive assistance following a model-based approach
  - Logic of a workflow is mapped in a process model
    - States describe start and end nodes of process steps
    - Actions contain information flow and stylesheet
    - Resources provide interfaces for M2M communication and content elements for visualization
  - Model is converted to JSON format
  - Visualized user interface (UI) is generated from JSON
  - UI is used on mobile device
  - Information about proceeded steps is transferred to cloud server

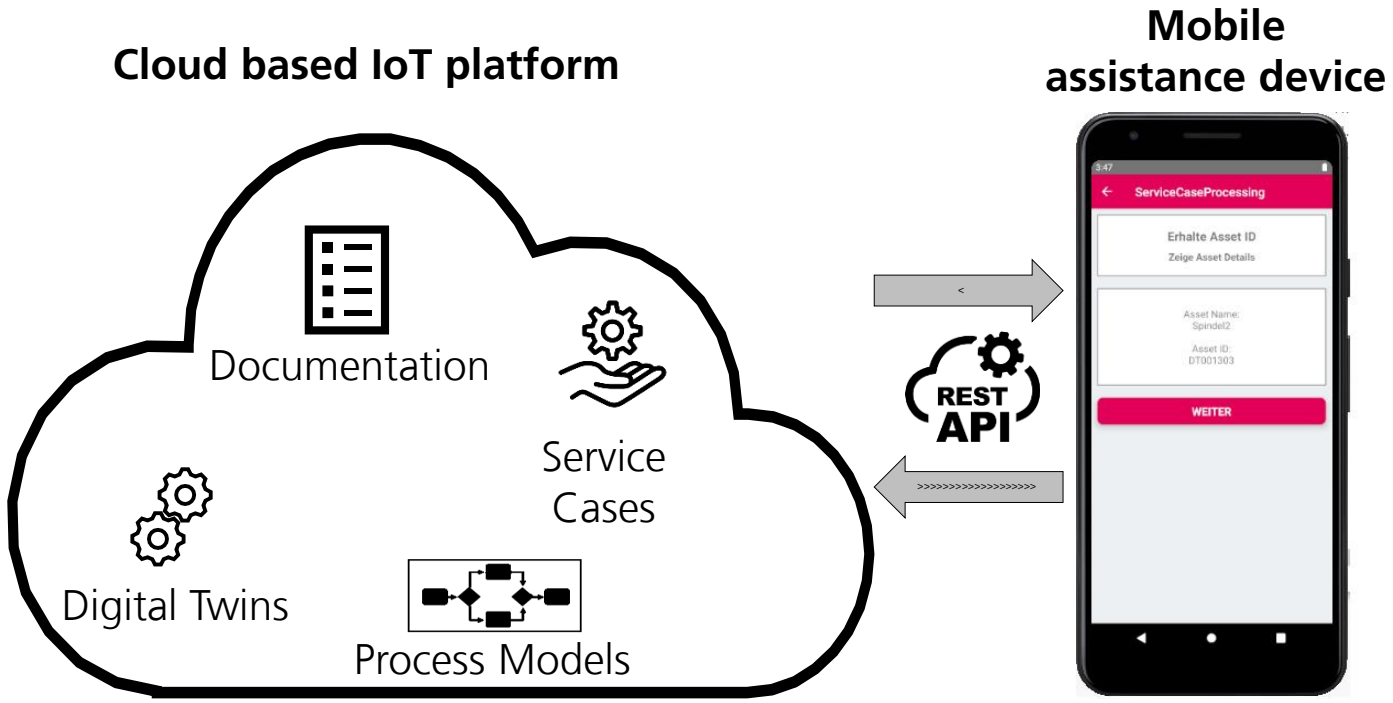


Context-Sensitive Assistance for Smart Maintenance Activities

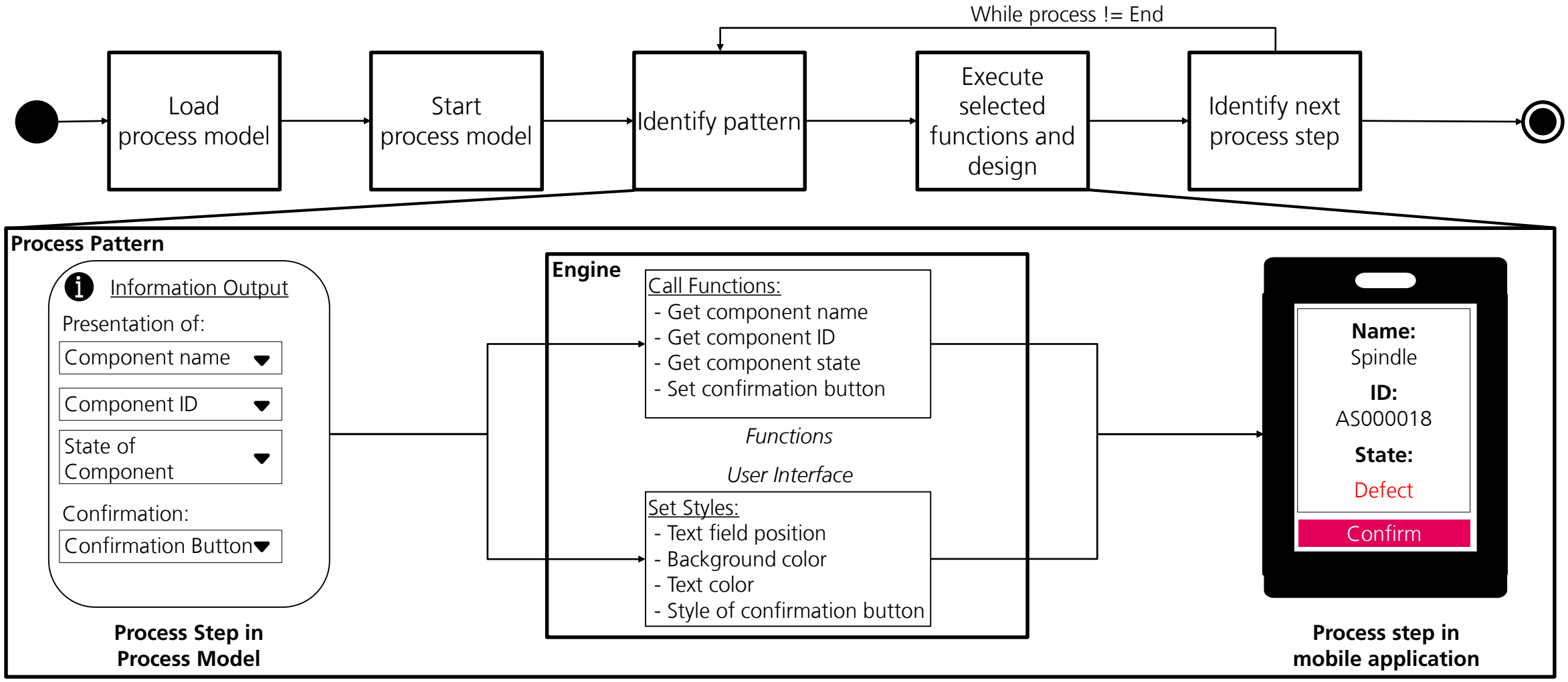
IoT platform contains information about:

- Products to be maintained (Digital Twins)
- Steps of the general maintenance process (Process Models)
- Linking of general process models and selected components (Service Cases)
- Further information about products or service cases (Documentation)

Real-time linking of mobile devices with IoT platform enables the integration of Context sensitive information

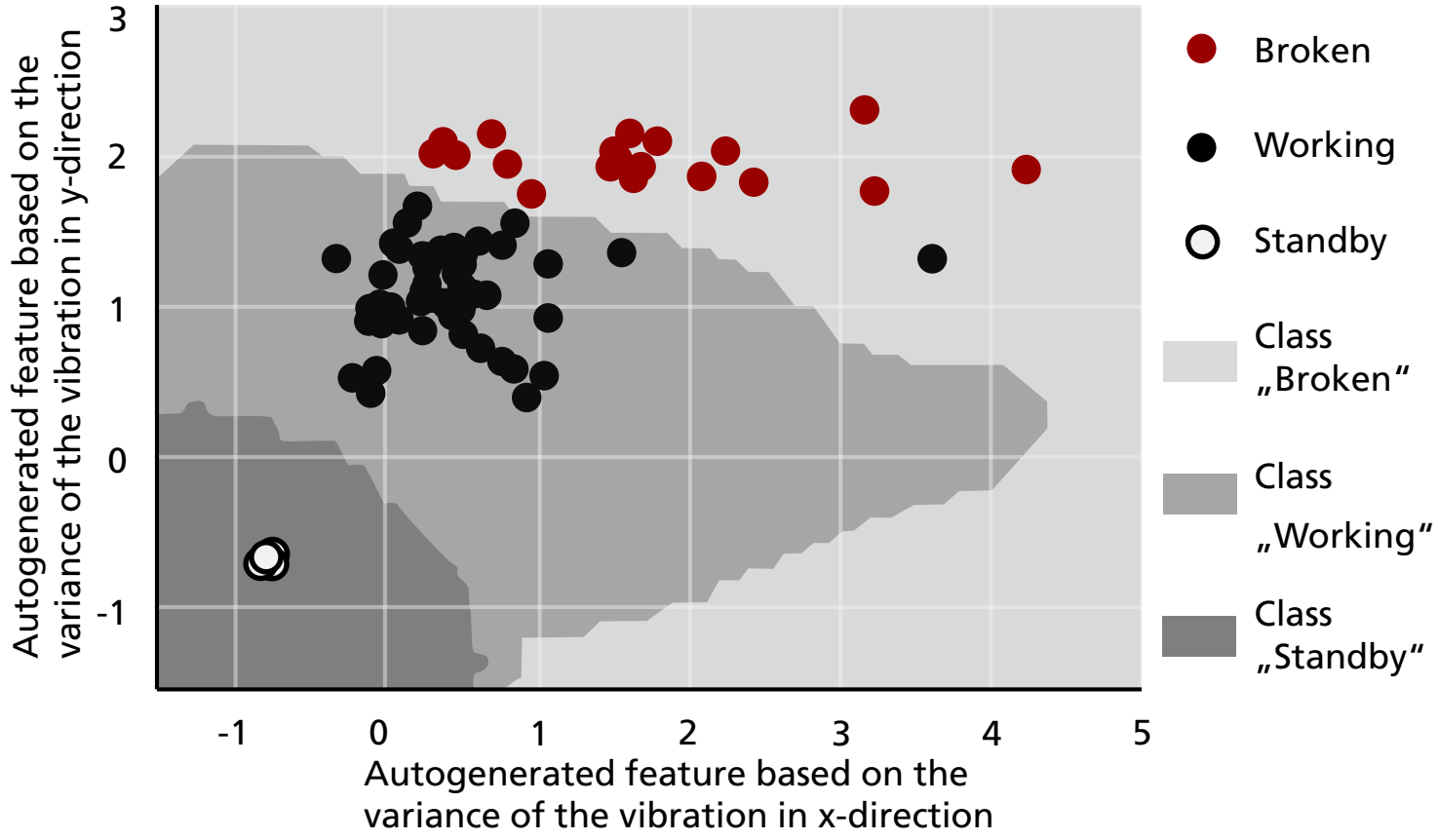


Simple Process Creation by Usage of Process Patterns



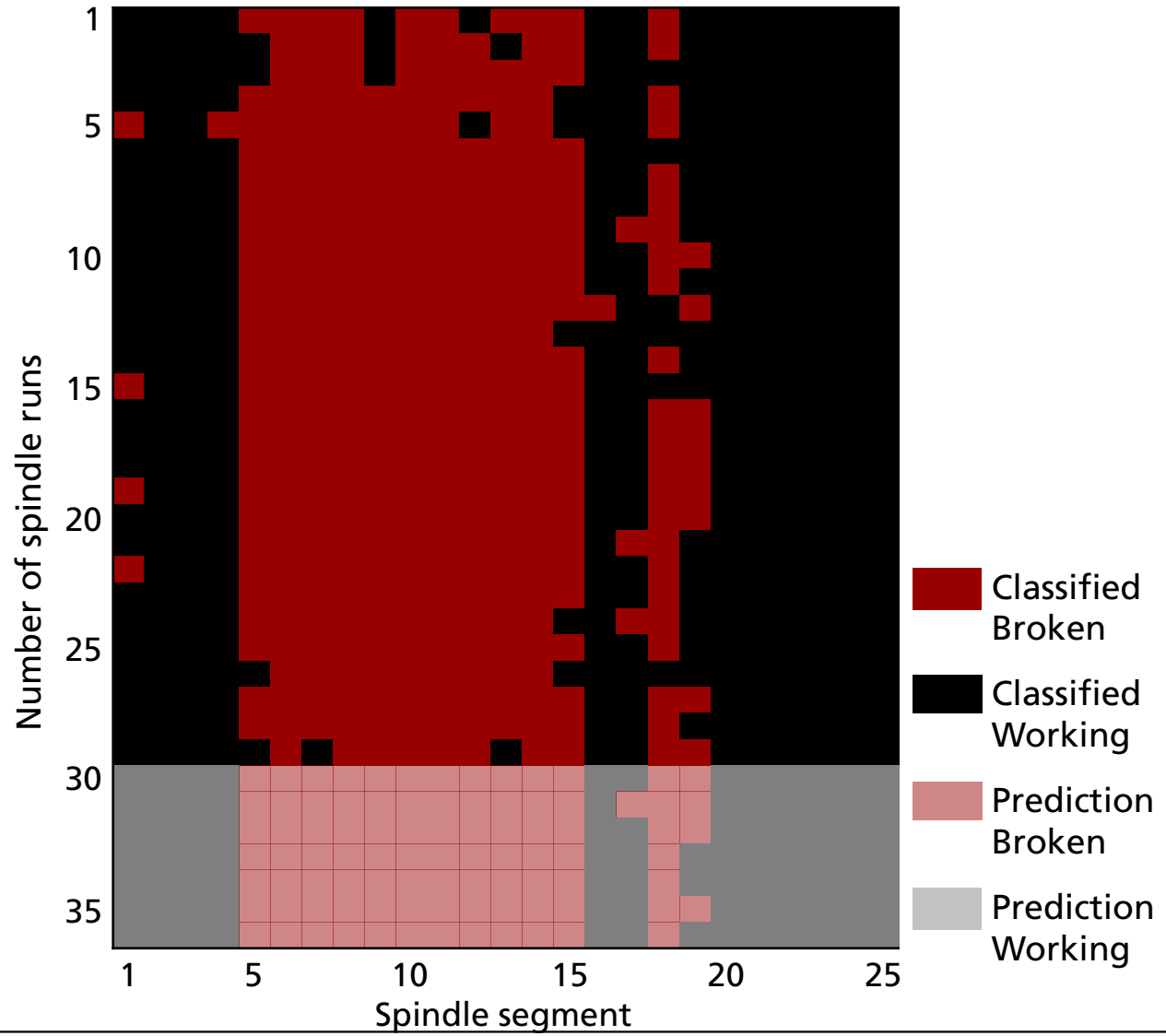
Condition Monitoring

- Classification Algorithms
  - Autoencoder
  - Support Vector Machine (SVM)
- Three states/classes (Damaged; Working; Standby)
- Hyperparameter tuning: 95% accuracy
- In real world scenarios closer to 92% based on empirical observations



Prediction of failures

- Prediction algorithm
  - Long Short-Term Memory (LSTM)
- Existing classification algorithms used for the classification of predicted behavior
- The goal of the prediction is to determine for certain sections of the spindle whether a damage can occur and at what specific point in the future

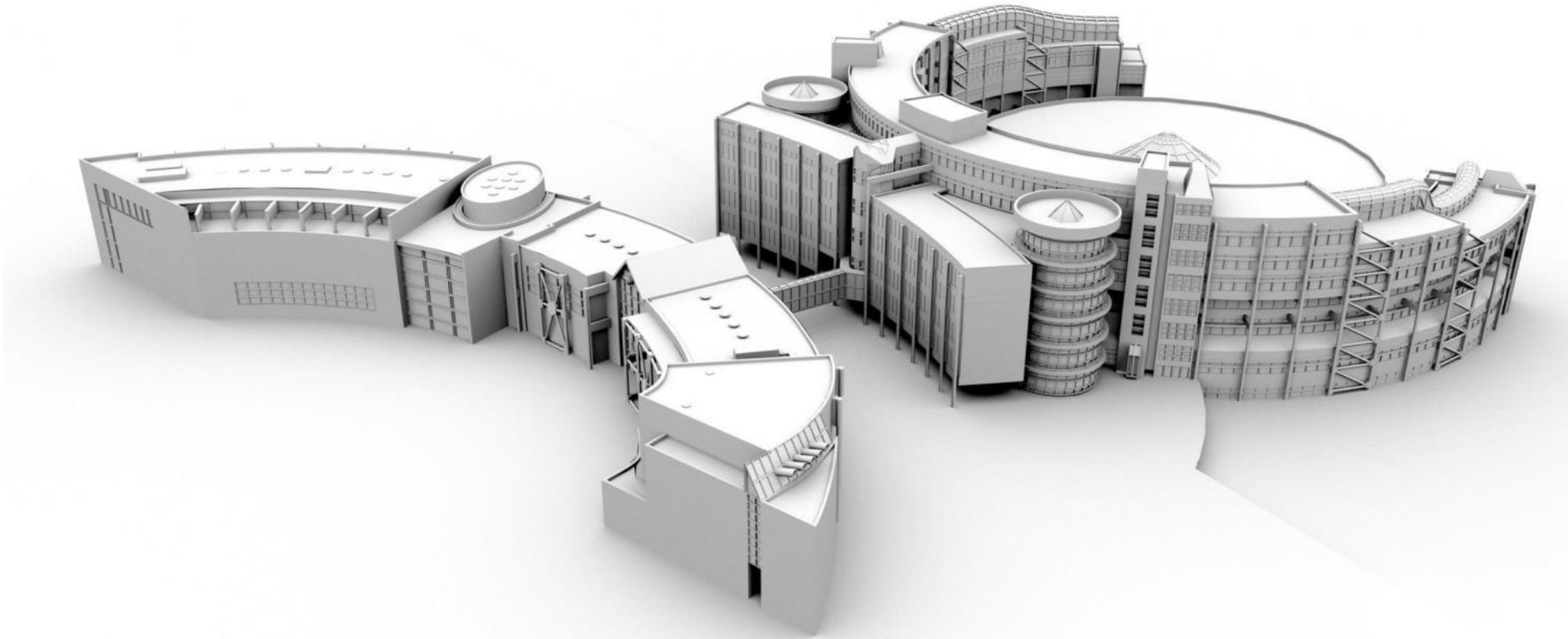


ROADMAP SMART MAINTENANCE

- Define **use case**
- Define the **IIOT architecture**
- Selection of suitable **sensor technology**
- Standards for **data, formats, interfaces**
- **Data acquisition**
- Documentation and evaluation of **operating states**
- Selection of **suitable AI methods**
- **Modelling**
- **Application-related data analysis, classification & prediction**
- **Adapted maintenance strategy**

THANK YOU FOR YOU KIND ATTENTION!

Questions?



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