Data processing for humans

Assistance systems for Engineering

Data processing and integration [illegible]

Architecture models (reference architecture) for a category of aggregation/modules related to properties, capabilities, interfaces…

CPPS ⇔ Industry 4.0 ⇔smart data challenges in research from a German perspective

Intelligent products and [illegible]

Communication and data consistency

Production units with inherent capabilities

Appropriation of necessary data for configuration, production, negotiation

Data analysis of process and alarm data and connection with engineering data

World wide distribution of data, high availability, access protection

Flexible production units, adaptable to modified product requirements, allow also structural changes

Data consistency about different „stakeholders“ in different engineering phases and crafts

Description of product and operating resources, e.g. ontology, for independent analysis, presentation, organisation and execution of a production process

Digital networks and interfaces for communication (between machine, human and plant, plant and plant)

Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

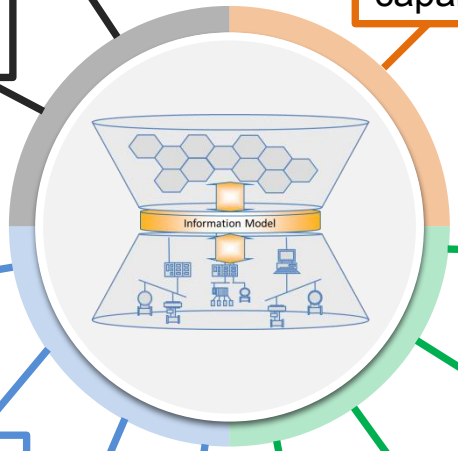
Univ.-Prof. Dr.-Ing. Birgit Vogel-Heuser
Full professor and head of chair
Automation and Information Systems (AIS)
Faculty of mechanical engineering, Technical University of Munich, Germany
www.ais.mw.tum.de; vogel-heuser@tum.de

CPPS ⇔ Industry 4.0 ⇔smart data challenges in research from a German perspective

Data processing for humans

- **Assistance systems for Engineering**
- **Data processing and integration for humans**

Architecture models (reference architecture) for a category of aggregation/modules related to properties, capabilities, interfaces…



Communication and data consistency

- **Appropriation of necessary data** for configuration, production, negotiation
- **World wide distribution** of data, **high availability, access protection**
- **Data consistency** about different „stakeholders“ in different engineering phases and crafts
- **Digital networks** and interfaces for communication (between machine, human and plant, plant and plant)

Intelligent products and production units

- Production units with **inherent capabilities**
- **Data analysis** of process and alarm data and connection with engineering data
- **Flexible production units**, **adaptable** to modified product requirements, allow also structural changes
- **Description of product and operating resources**, e.g. ontology, for independent analysis, presentation, organisation and execution of a production process

Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

Technical University of Munich

- The leading university in mechanical and electrical engineering in Germany

Rankings 2015

- Technical University of Munich:
  - 51st at the Academic Ranking of World Universities (Shanghai-Ranking)
  - 60th at the QS World University Ranking
- Faculty of Maschinenwesen:
  - 19th at the QS World University Ranking by Subject (1st in Germany)

Memberships Head of Chair

- Chair of VDI/VDE (Association of German Engineers) TC 5.15 “Multi-Agent Systems in Automation”
- Coordinator of CRC (Collaborative Research Center) 768 “Managing cycles in innovation processes”
- Co-Initiator of PP (Priority Programme) 1593 “Design for Future – Managed Software Evolution”

Scientific staff

- ca. **20** PhD students
- **9** technicians, trainees (software engineering)

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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Assistance systems for Engineering

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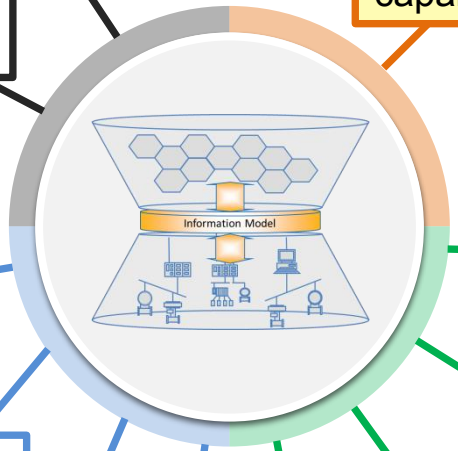

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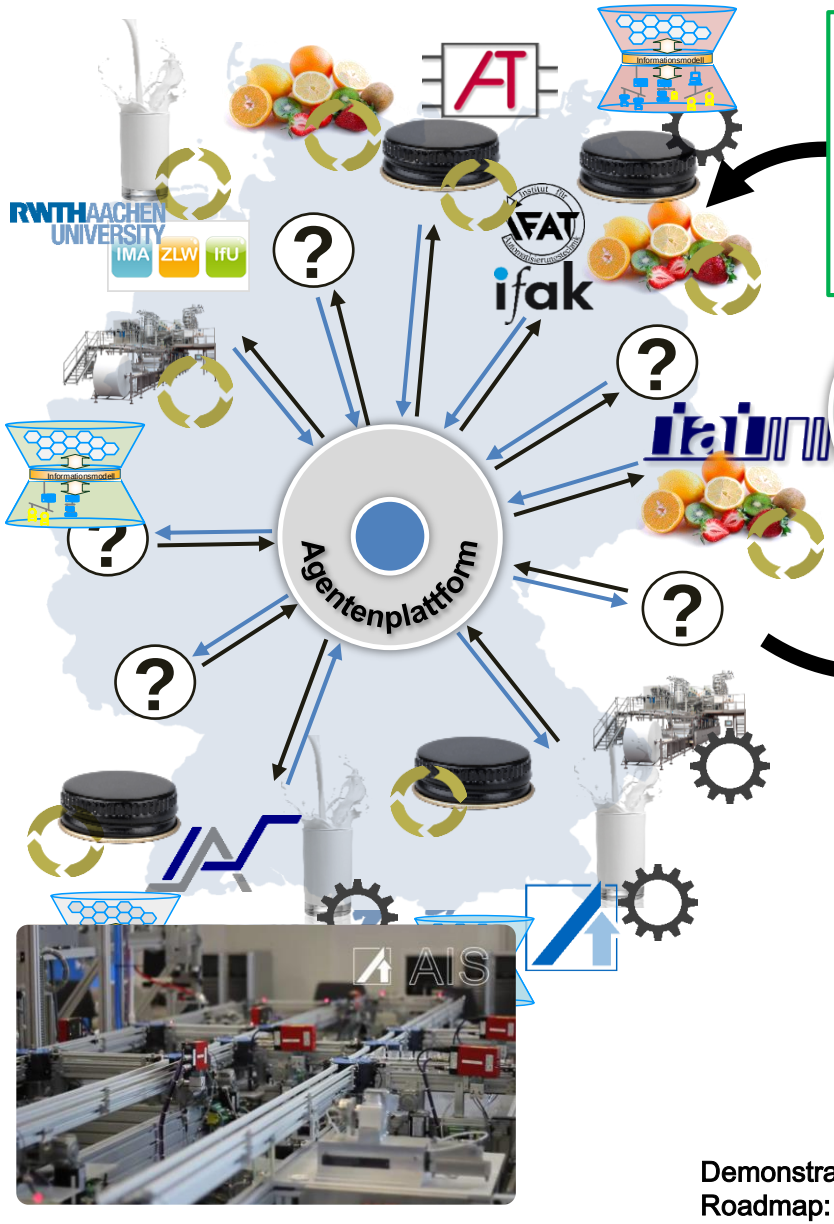
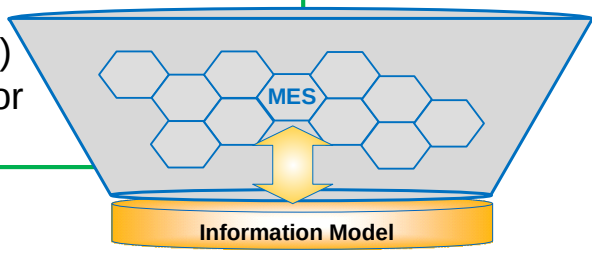
Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

My Joghurt – accepted Industrie 4.0 demonstrator



Description of the plant and its configuration:
- Technical Resources (Units)
- Capabilities (Operations)
- Units‘ status (e.g. PackML)
- relevant Data points e.g. for Tracking/Tracing



I4.0 Interface (TCP/IP)

CPPS-Agent
Representation of the plant

Communication Module
Routing messages

<<BaseAgent>>
Process-Agent
Supervision of process

<<BaseAgent>>
Whiteboard
Job offers, job states

<<BaseAgent>>
Resource-Agent
Represents plant module
Scheduling for jobs

<<BaseAgent>>
System-Agent
Structure of the plant,

IEC 61131-3 Software Application

Now officially part of the PLATTFORM INDUSTRIE 4.0 roadmap

Demonstrator: http://i40d.ais.mw.tum.de
Roadmap: http://www.plattform-i40.de/I40/Navigation/DE/In-der-Praxis/Karte/karte.html

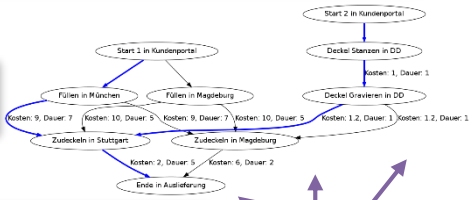
Procedure of production control

Customer places order

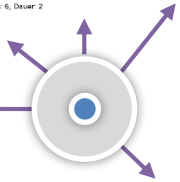
Splitting orders into sub-orders

Collecting prices and deadlines for sub-orders of system

Determine (new) schedule



Contracting (new) sub-orders



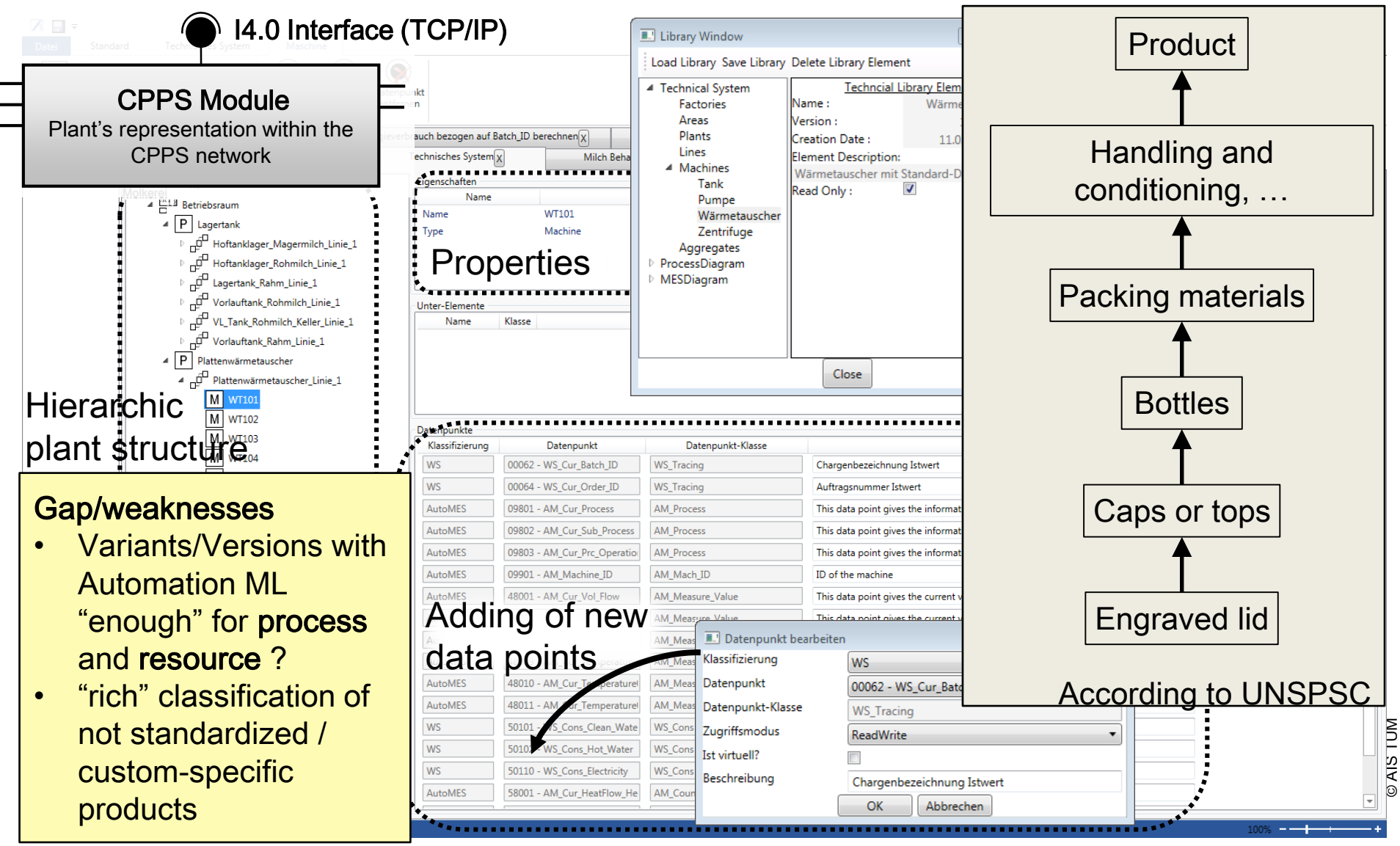
Production monitoring (operator and customer)

e.g.

Automatic troubleshooting

Send status report

Product, Process, Ressource using MES-ML

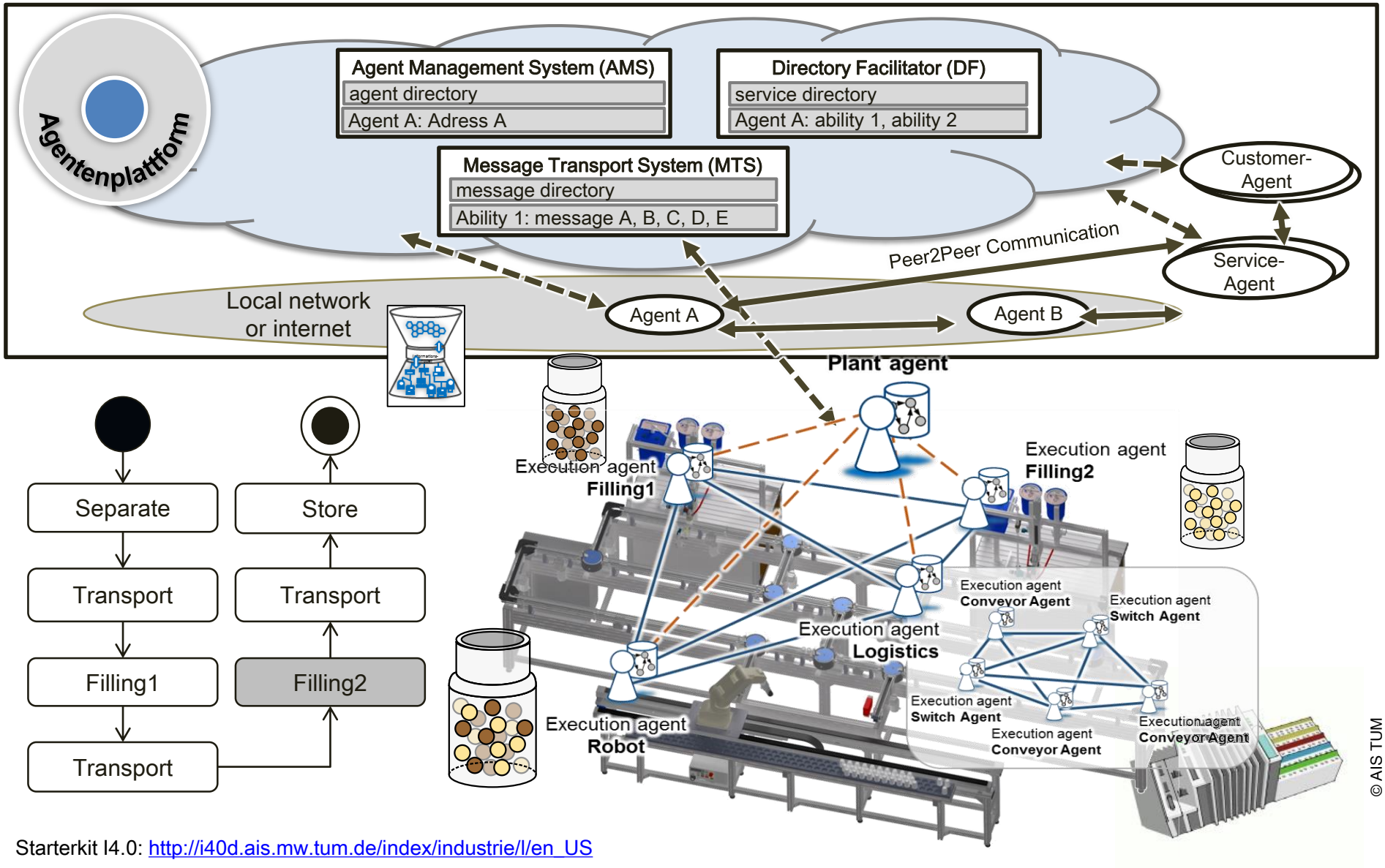


Gap/weaknesses

- Variants/Versions with Automation ML "enough" for **process** and **resource** ?
- "rich" classification of not standardized / custom-specific products

MES-ML: Witsch, M.; Vogel-Heuser, B.: *Towards a Formal Specification Framework for Manufacturing Execution Systems*. In: IEEE Transactions on Industrial Informatics, Vol. 8, No. 2, 2012, PP. 311-320.

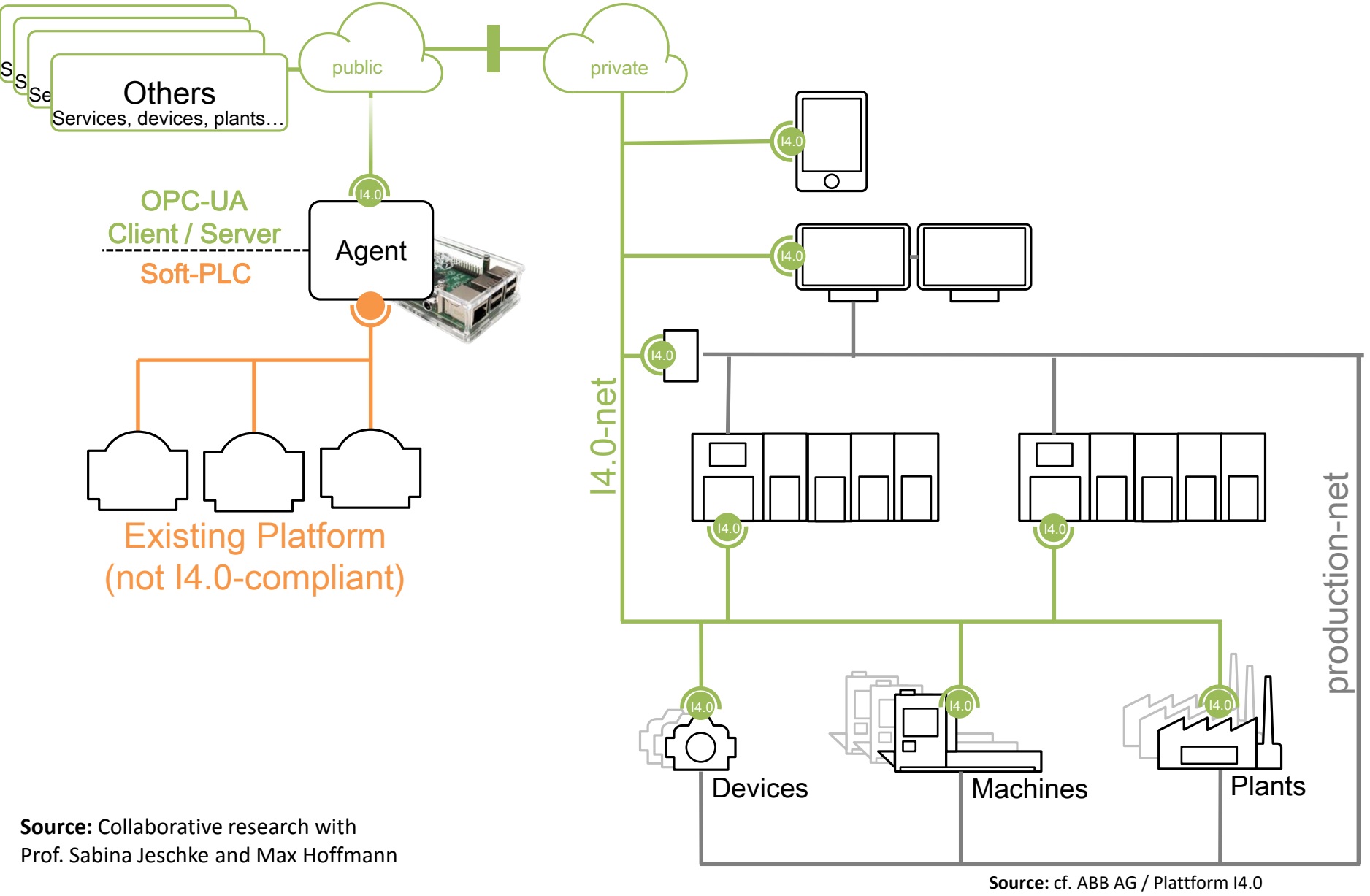
Self-adapatation of an CPPS



Starterkit I4.0: http://i40d.ais.mw.tum.de/index/industrie/I/en_US

Source: B. Vogel-Heuser: Herausforderungen und Anforderungen aus Sicht der IT und der Automatisierungstechnik. In: Industrie 4.0 in Produktion, Automatisierung und Logistik, Springer, 2014.

Agents as interfaces for Industrie 4.0 extensions to OPC UA or MQTT for CPPS



Source: Collaborative research with Prof. Sabina Jeschke and Max Hoffmann

Source: cf. ABB AG / Plattform I4.0

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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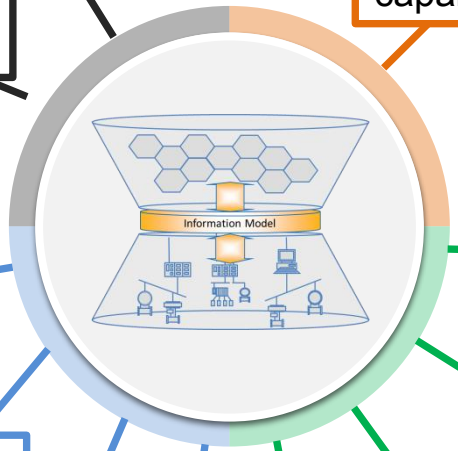

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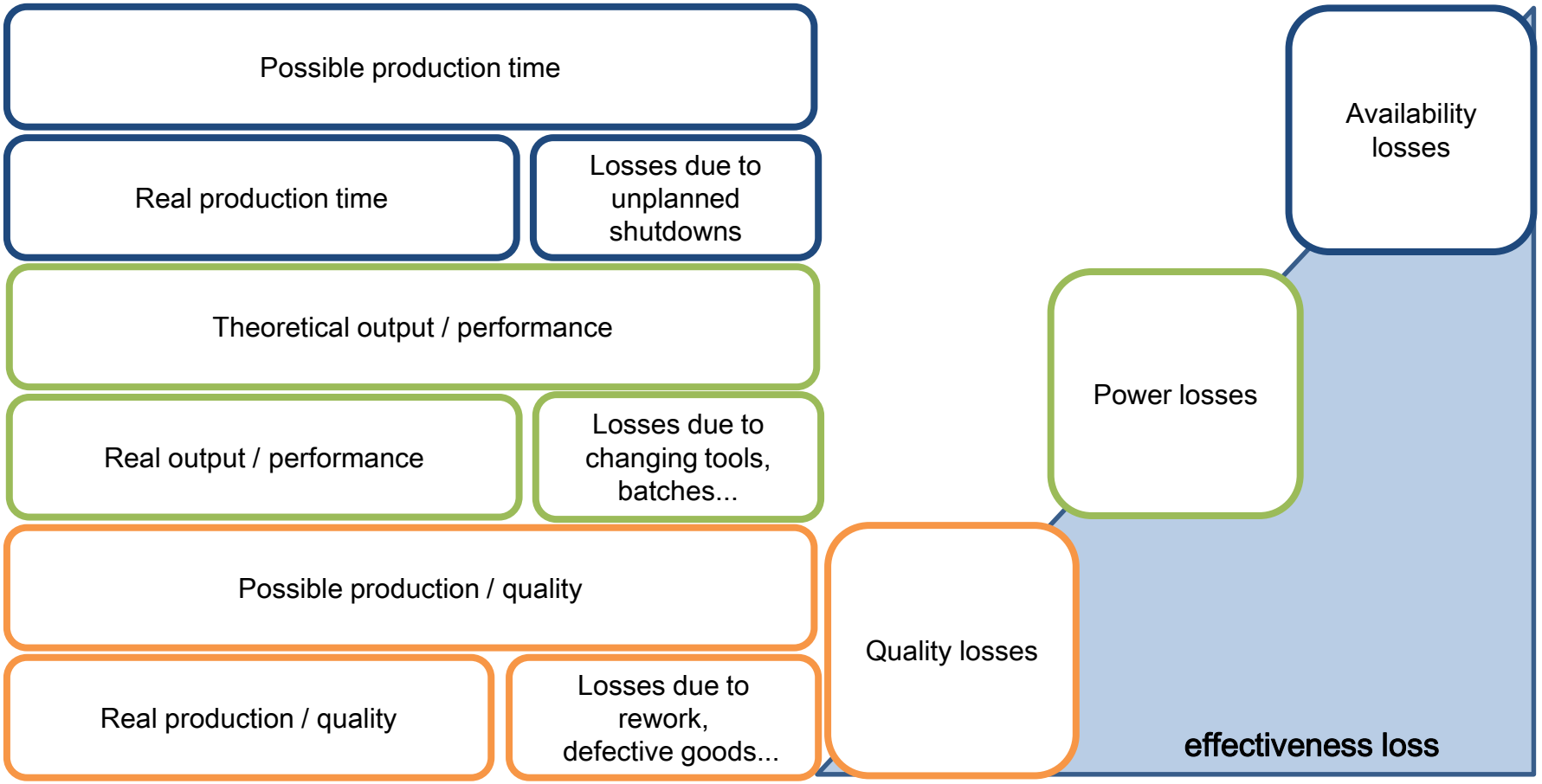
Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

Overall equipment effectiveness (OEE)

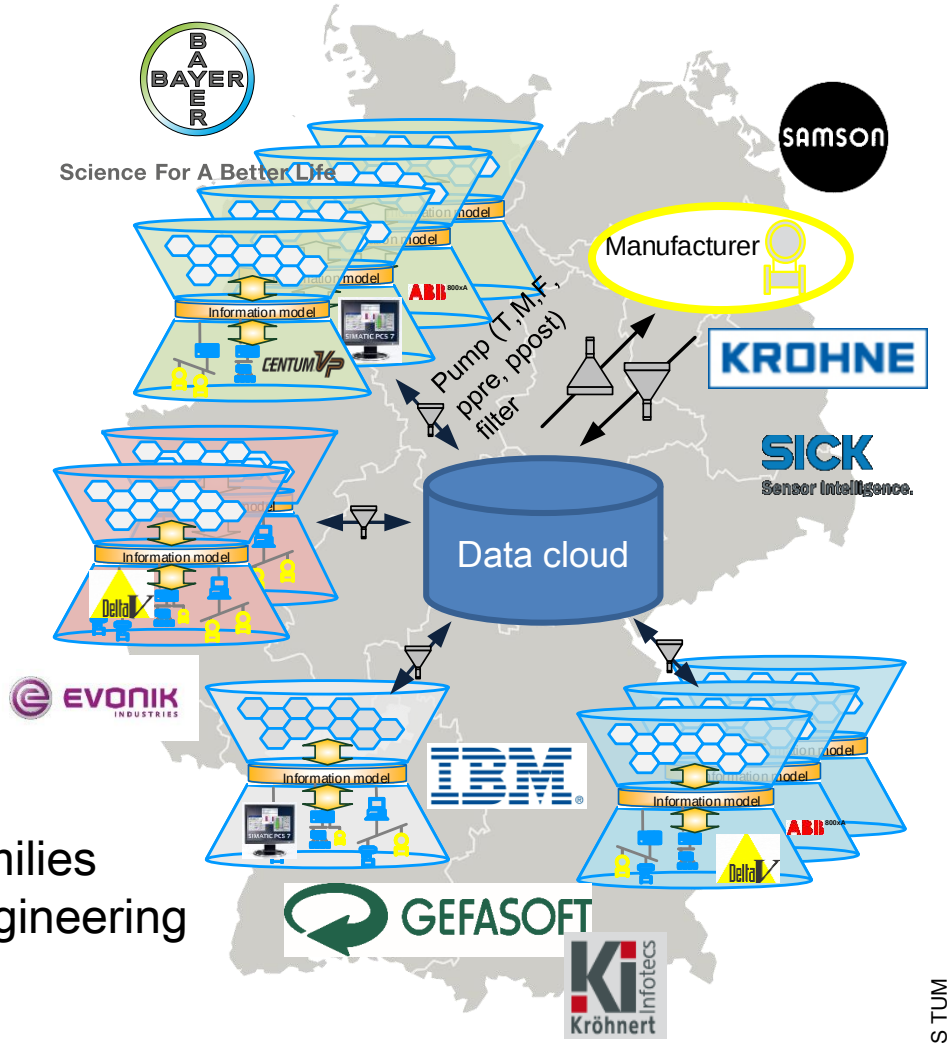


Project: #SmartData2015 / Data Mining in process industry

- Data logistics
  - Secure provision and transport
  - Secure storage
  - Data model

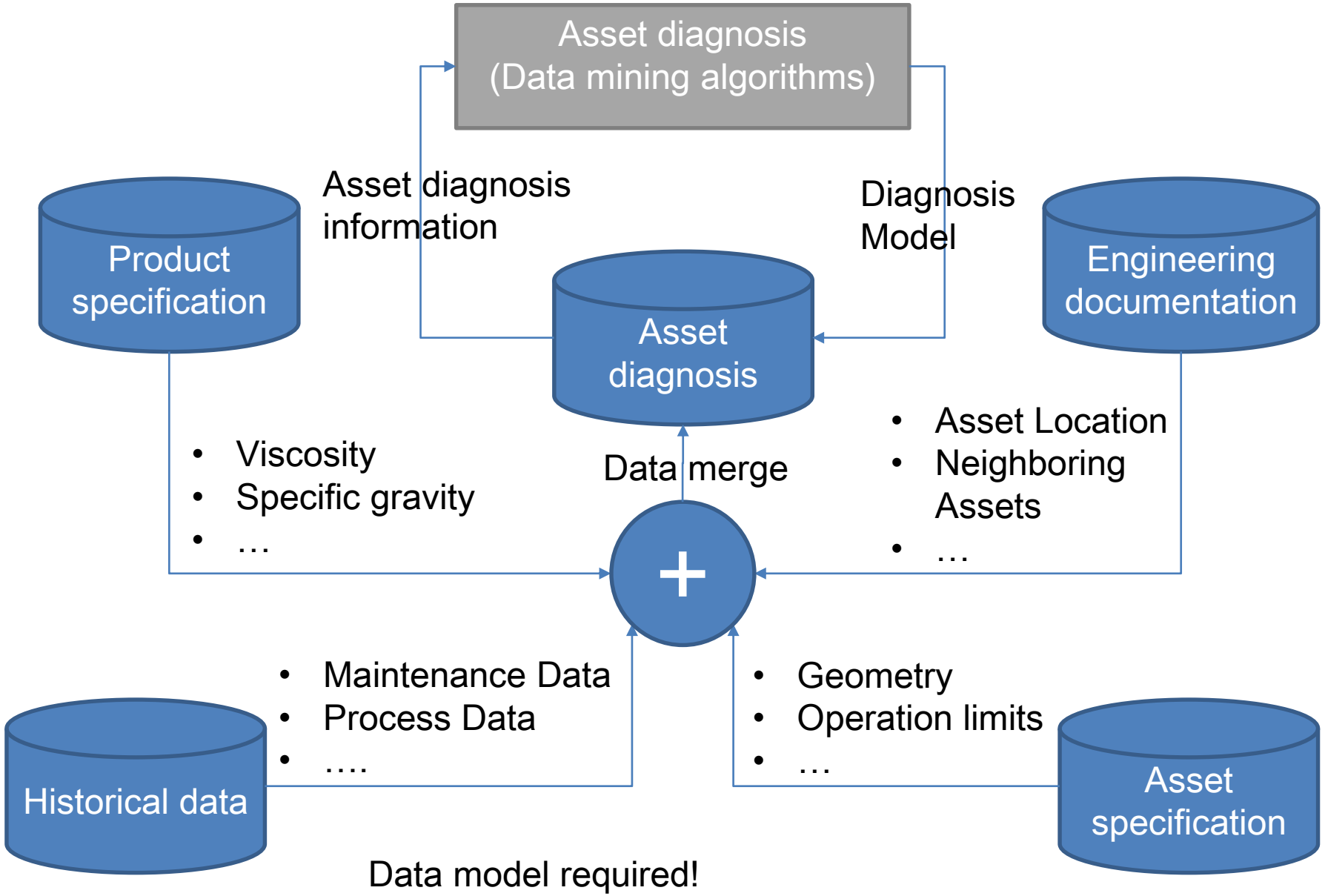
- Aggregation and analysis of data
  - ➢ Identification of unknown correlations in data
  - ➢ Integration of field device manufacturers

- Data use
  - ➢ Application of the findings to plant families
  - ➢ Supporting operating personnel in engineering and maintenance



https://www.ais.mw.tum.de/en/research/current-research-projects/sidap/

Data logistics and data model



Quality forecast in the fibreboard manufacture

Historical Information:
- Commision
- Shift
- Day
- Month

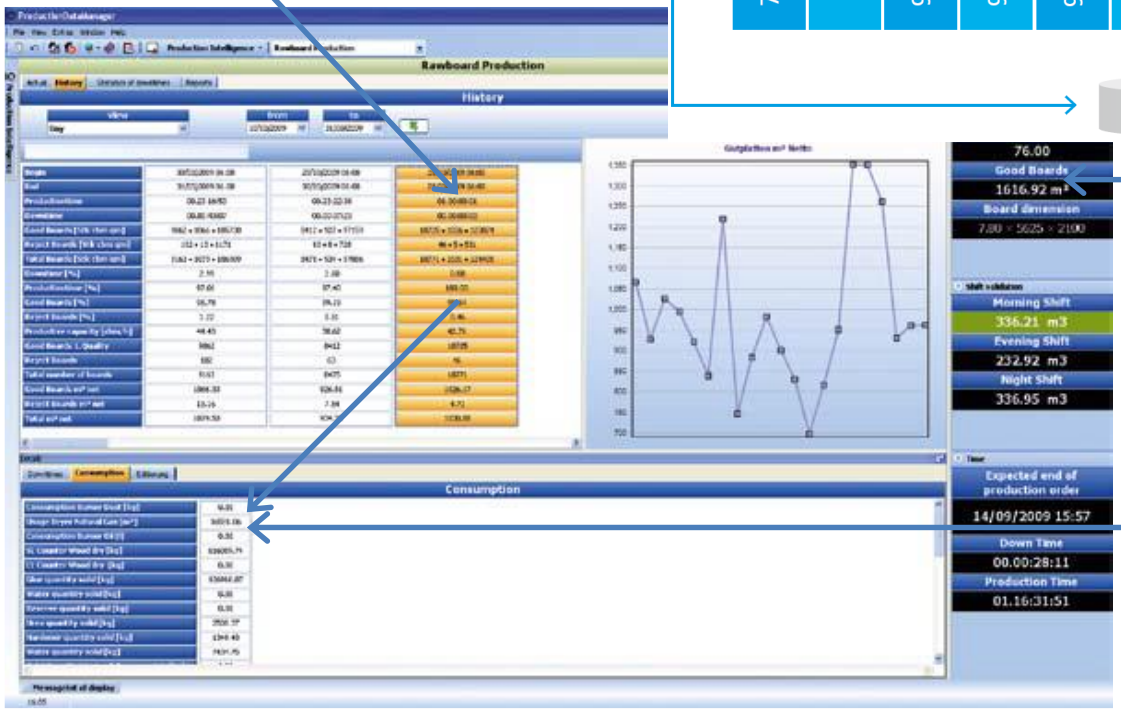
(exportable to Excel)
+ generate reports

Material flow tracking with lab report

temperature dryer outlet	...	CL-glue/furnish blending factor	moisture of blended CL-furnish	weight-per-unit-area mat former	prepress pressure infeed	temperature main heating 1	...	temperature main heating 5	spec. pressure frame 38 center	thickness	lab sample	internal bond (IB)	bending strength (MOR)
170.90 °C	...	8.60 %	6.30 %	27.90 kg/m²	128.20 bar	227.30 °C	...	195.60 °C	50.19 bar	19.44 mm		0.43 N/mm²	...
7:45:00	...	9:53:19	9:56:26	9:57:17	9:57:31	9:58:27	...	9:59:30	9:59:38	9:59:55	10:00:00	12:00:00	...

1 dataset

Current information



Details:
- Downtimes
- Consumptions
- …

Editor for corrections

Source: Siempelkamp Maschinen- und Anlagenbau GmbH & Co. KG, Prod-IQ

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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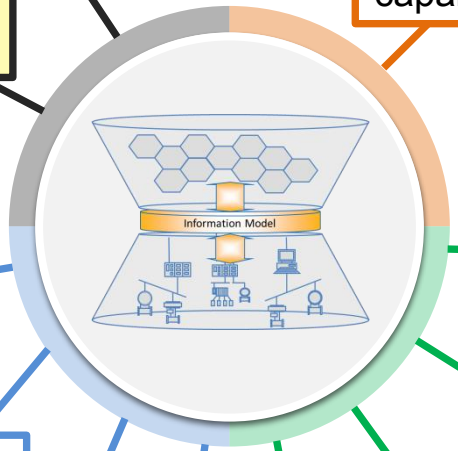

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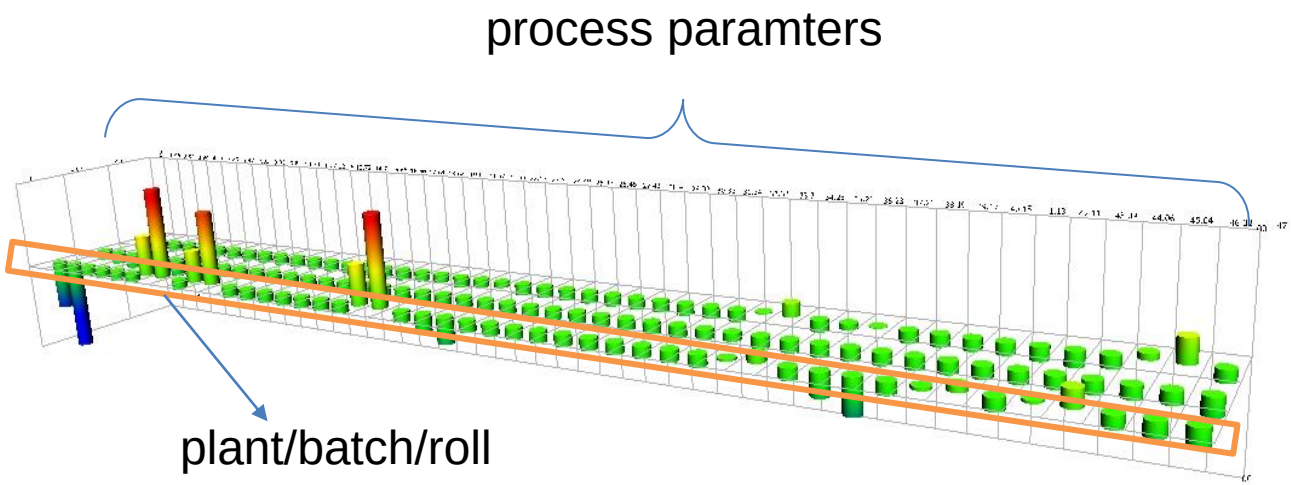
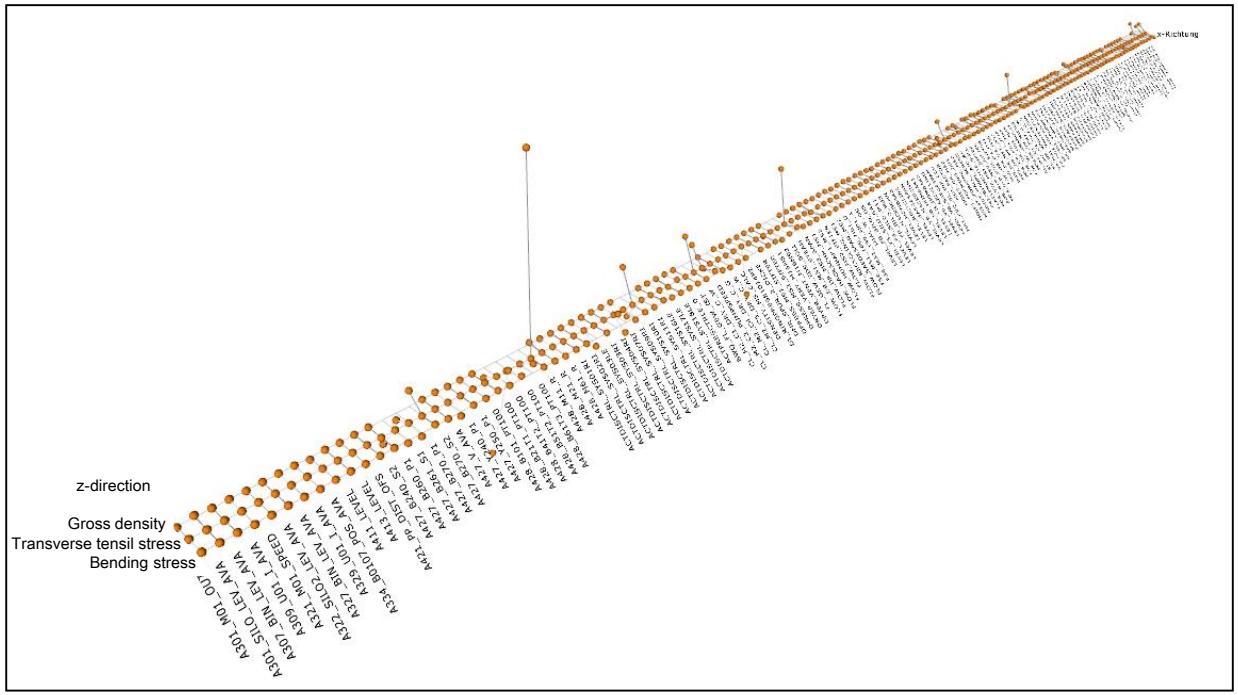
Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

Vizualization of parameters- chipboard manufacturing

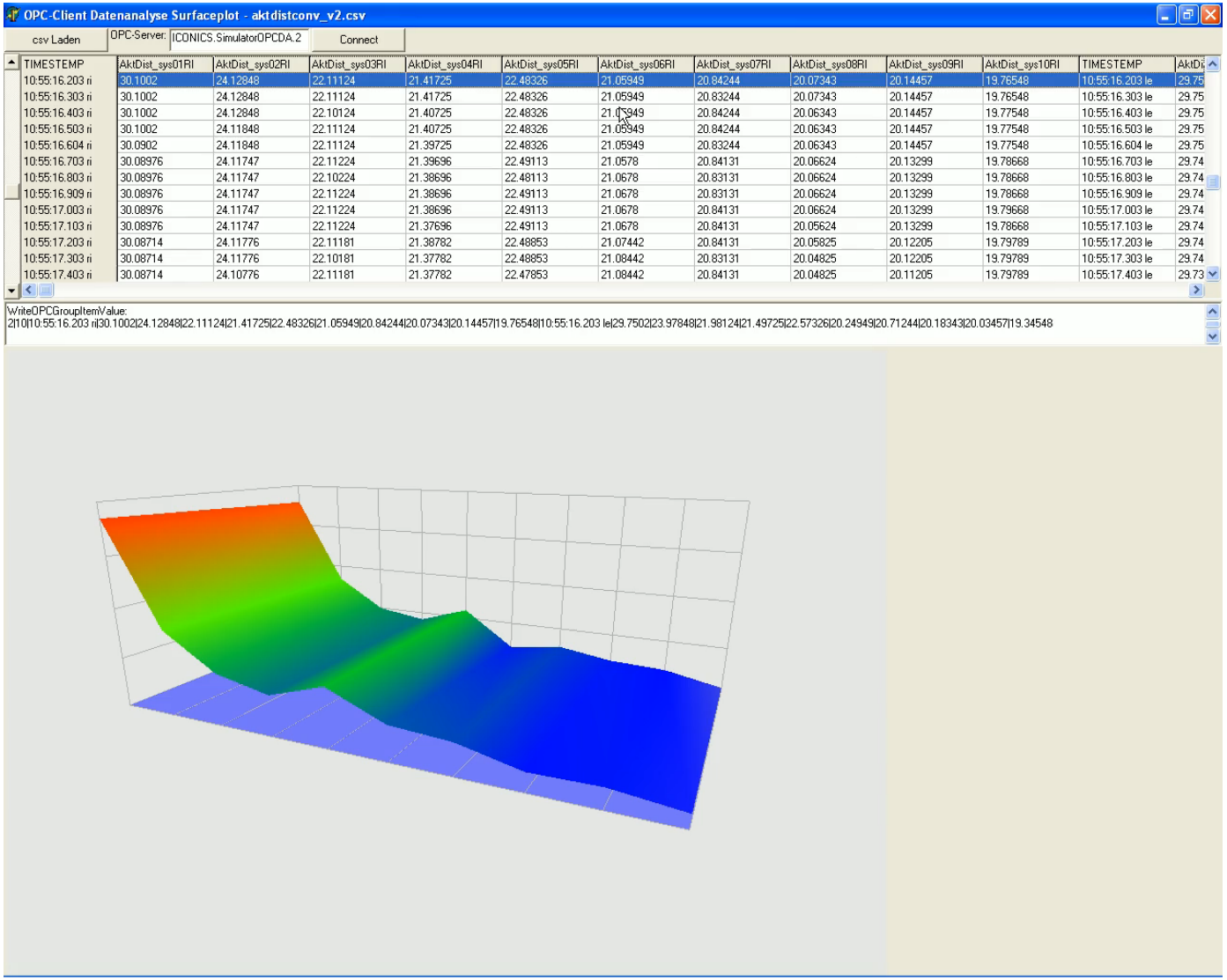


Comparison of plant parameters with different plants/batches

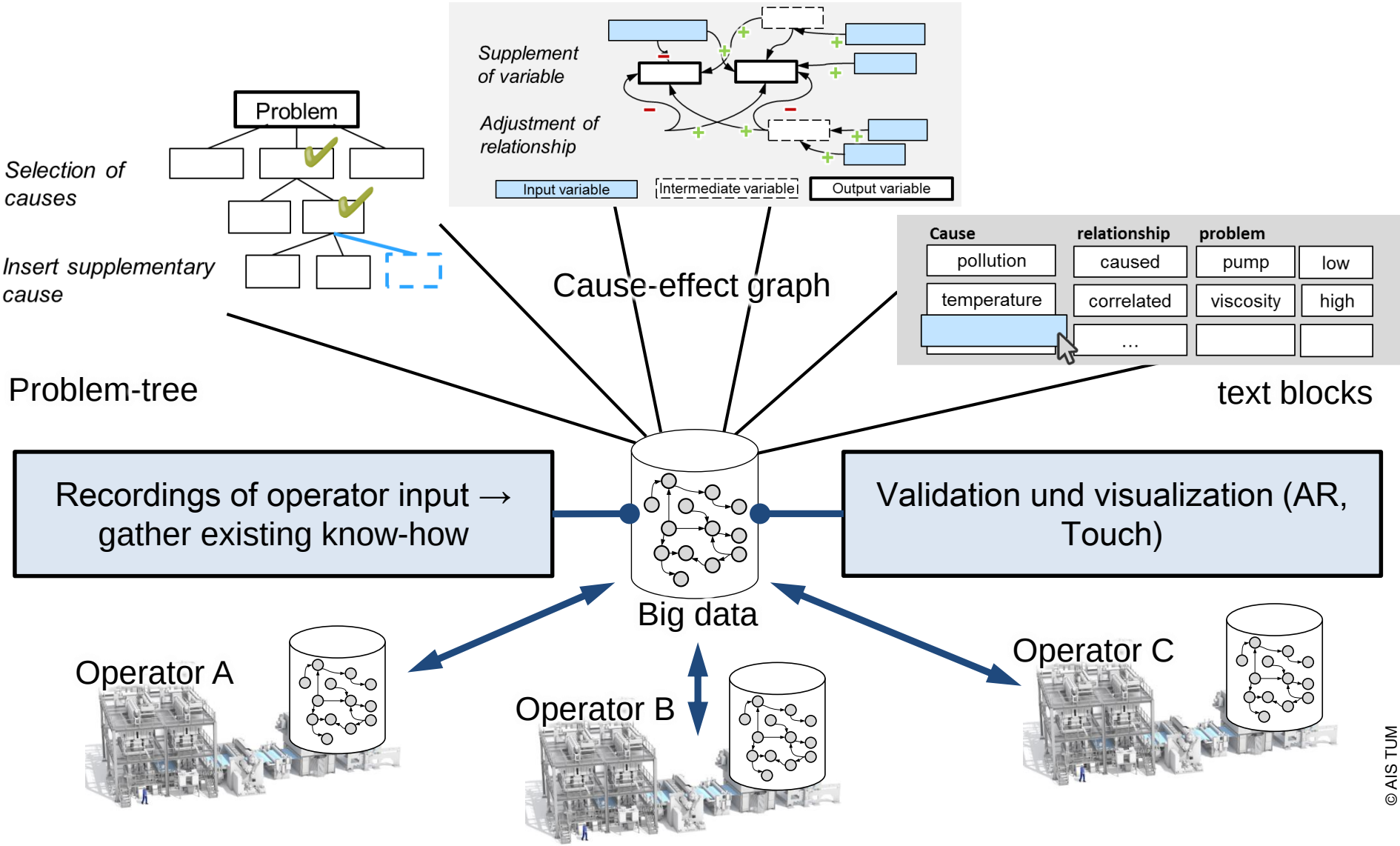


Influence of process parameters on quality criteria

Data player- process infeet particle board press

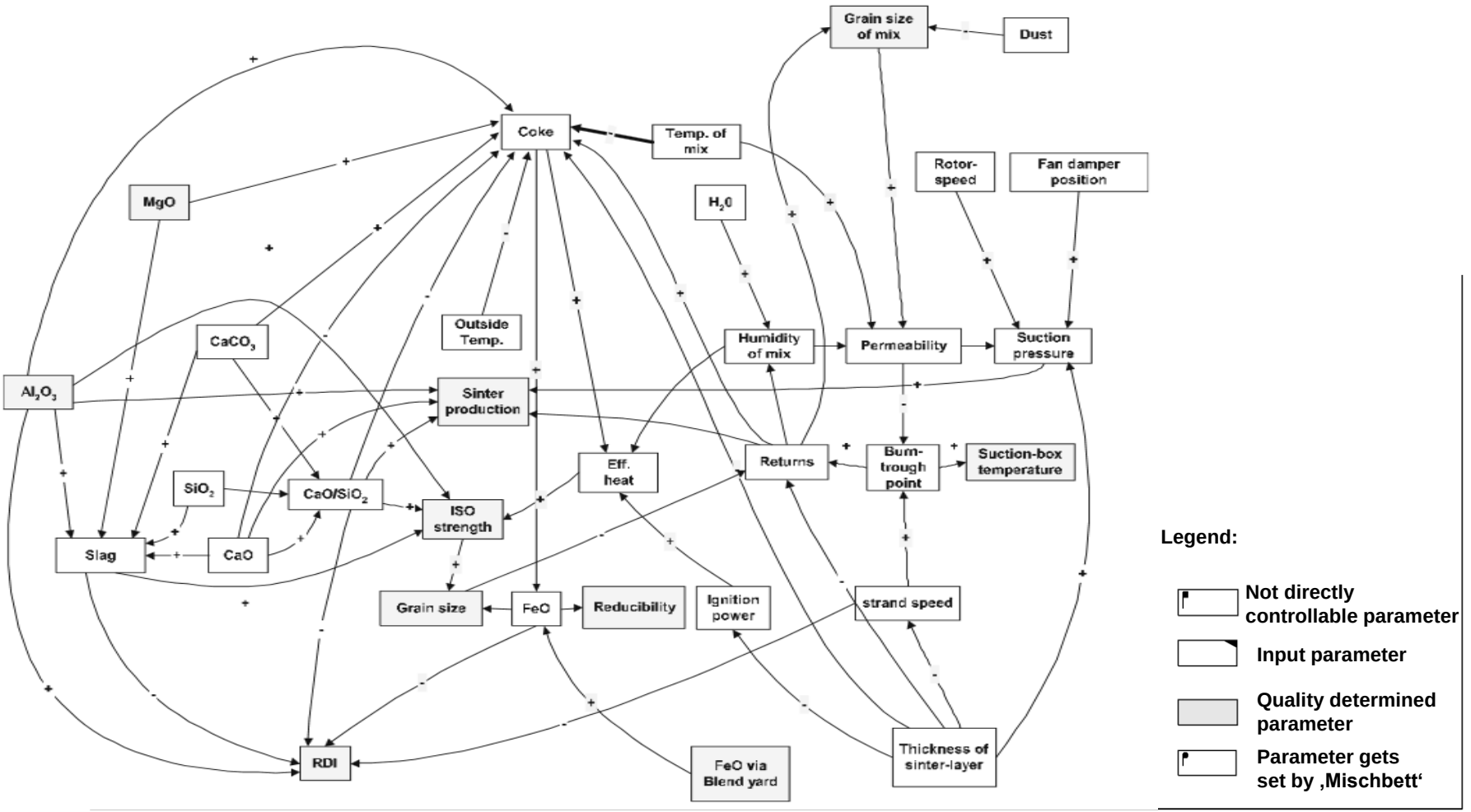


Fleet management and Integration of operator staff



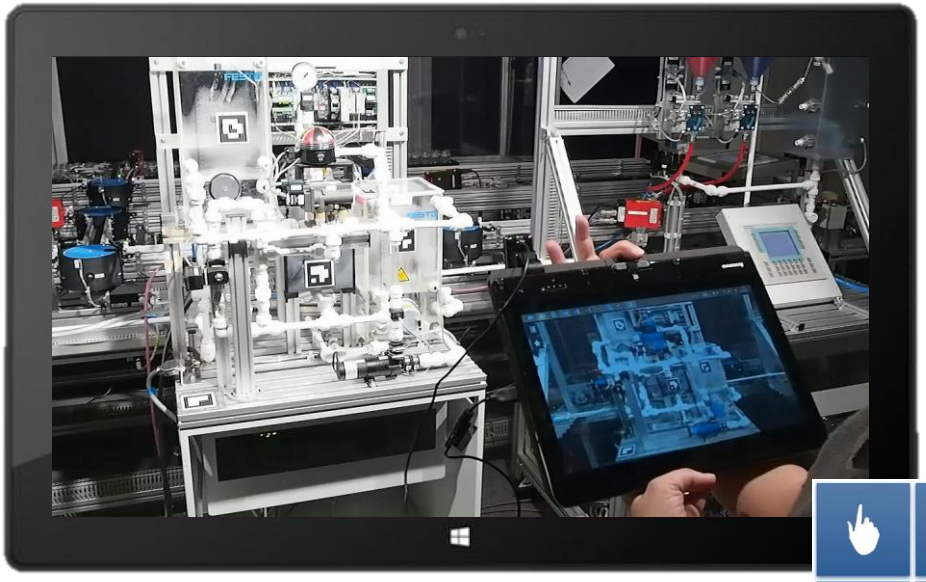
Source: Institute of Automation and Information Systems, TU München https://www.ais.mw.tum.de/en/research/current-research-projects/improve-eu-project/

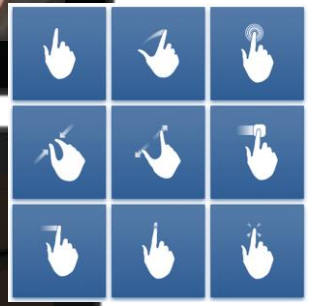
Cause-effect-graph of a sintering plant

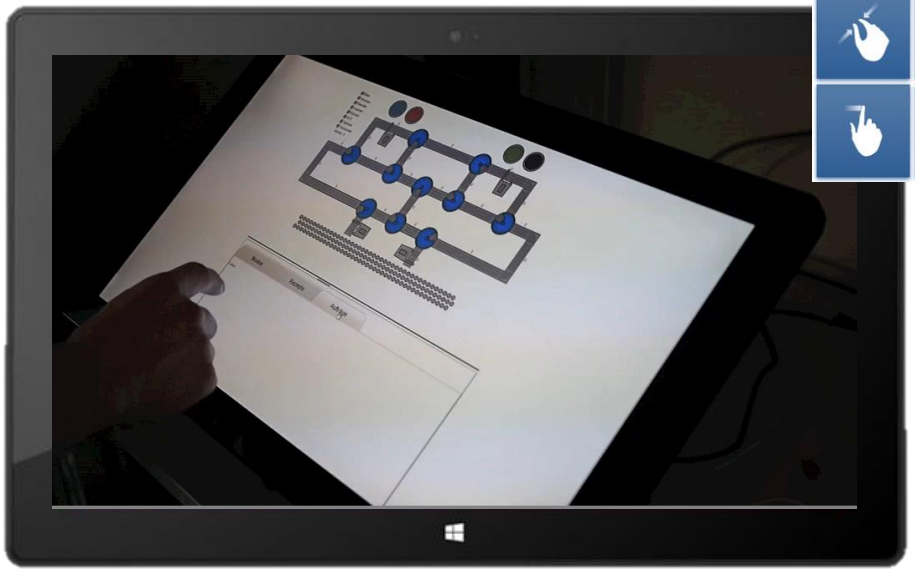


Source: Langer, M.; Vogel-Heuser, B.: *Synthesis of a plantwide quality prediction system for a sintering plant*. In: 15th World Congress of International Federation of Automation Control (IFAC), Barcelona, 2002.

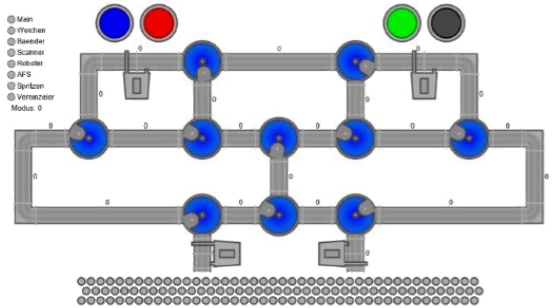
Information aggregation for maintenance staff







- Mobile devices with touchscreen
- Augmented Reality supports optimization and maintenance of industrial plants



Information aggregation for maintenance staff

Role shift supervisor | Shift supervisor undertakes role of mechanic | Shift supervisor undertakes role of operator

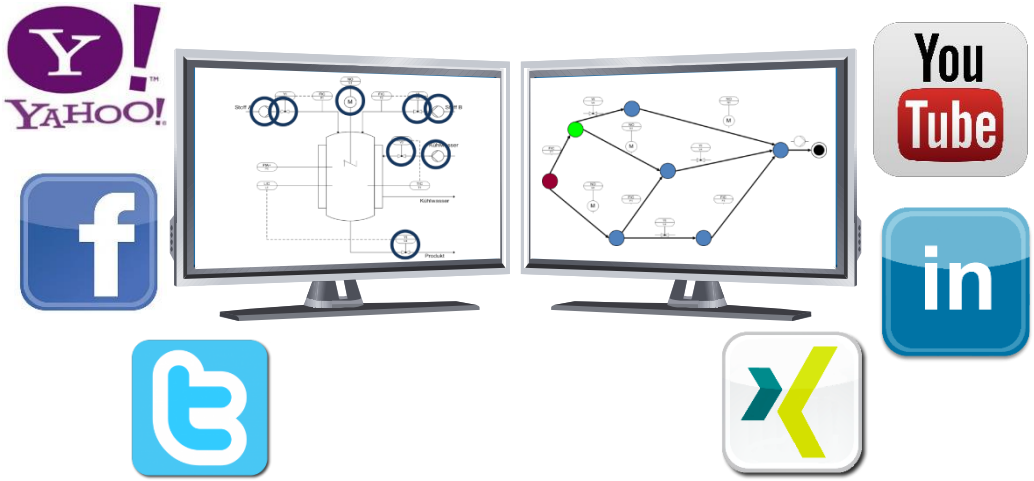
Shift supervisor

- Red-green color blindness
- Preferred voice control

Role

- Shift supervisor
- Mechanic
- **Operator**

Context

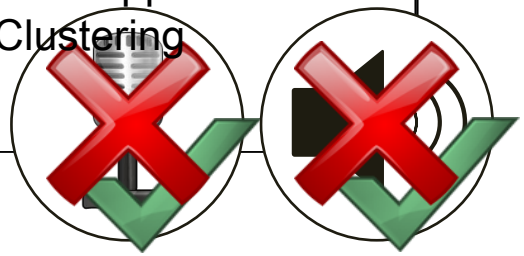


Challenge

- Prediction of critical situations based on analysis of process data and alarm sequences
- Recommendations for operator

Approach

- Pattern analysis, statistical approaches and Clustering



Industry 4.0 - puzzle pieces- open research issues

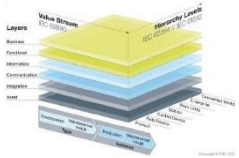
Data processing for humans

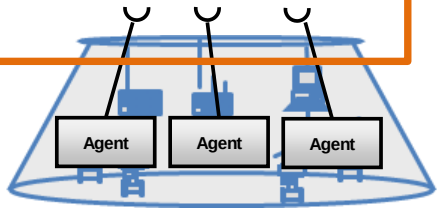
Data processing and integration for humans

SFB 768

IMPROVE

Architecture models





Marketplace of production units

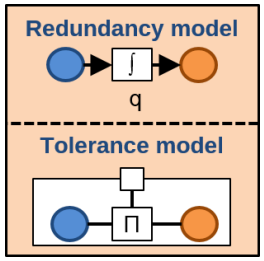
Intelligent products and production units

Reconfiguration, recovery, restart of production units

Data analysis of process and alarm data and connection with engineering data

SODAP

Data consistency about different „stakeholders“ in different engineering phases and crafts



Production units with inherent capabilities (learning)

Description of product (classification and ontologies) – consistency checking

MODEMMiCAS

AutoMES

Prozesszustandsbasiertes Energiemonitoring von Produktionsanlagen durch MES

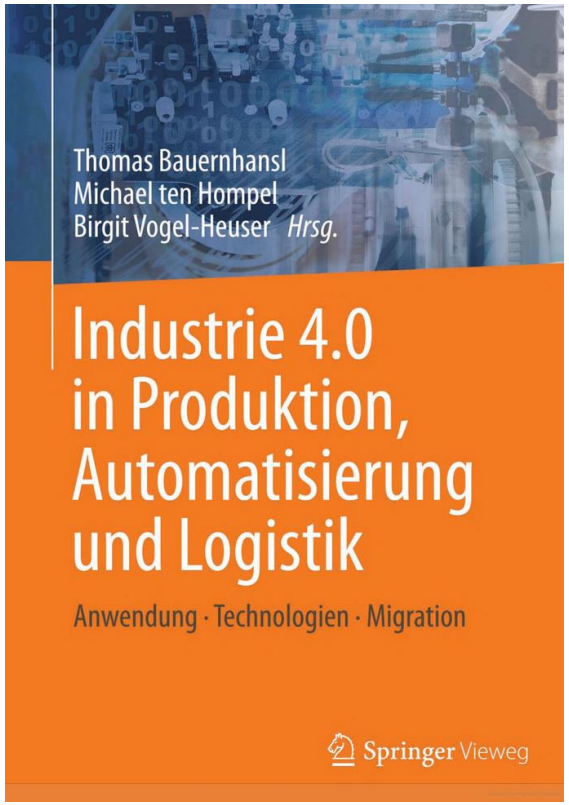
Flexible production units, adaptable to modified product requirements, allow also structural changes

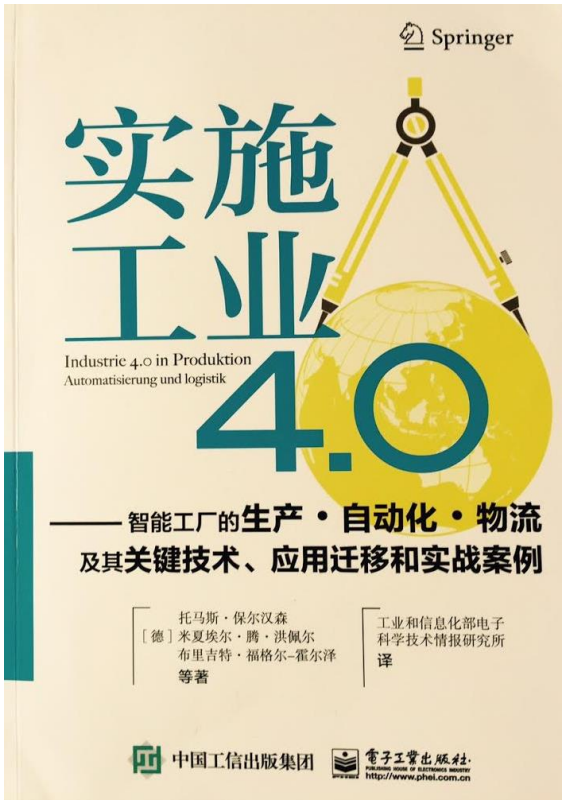
- Metrics have to be adapted / further developed for benchmarking aPS designs and operation behavior regarding Industry 4.0

Source: Vogel-Heuser, B.; Rösch, S.; Fischer, J.; Simon, T.; Ulewicz, S.; Folmer, J.: *Fault handling in PLC-based Industry 4.0 automated production systems as a basis for restart and self-configuration and its evaluation*. In: Journal of Software Engineering and Applications, Vol. 9, No. 1, 2016, PP. 1-43.

Industrie 4.0 - References

Print to appear Oct. 2016





Authors: Birgit Vogel-Heuser, Thomas Bauernhansl, Michael ten Hompel
Handbuch available online:
http://link.springer.com/referencework/10.1007%2F978-3-662-45537-1

Thank you for your attention.

http://i40d.ais.mw.tum.de

Slides will be available soon via link from homepage

www.ais.mw.tum.de

Univ.-Prof. Dr.-Ing. Birgit Vogel-Heuser
Full professor and head of chair
Automation and Information Systems (AIS)
Faculty of mechanical engineering, Technische Universität München
www.ais.mw.tum.de; vogel-heuser@tum.de

Selected related publications

- **U. Frank, J. Papenfort, D. Schütz:** Real-time capable software agents on IEC 61131 systems – Developing a tool supported method. In: Proc. of 18th IFAC World Congress, Mailand, Italien, 2011, S. 9164-9169.
- **C. Legat, B. Vogel-Heuser:** A Multi-agent Architecture for Compensating Unforeseen Failures on Field Control Level. In: International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing and Robotics (SOHOMA), 2013.
- **F. Li, G. Bayrak, K. Kernschmidt, B. Vogel-Heuser:**: Specification of the Requirements to Support Information Technology-Cycles in the Machine and Plant Manufacturing Industry. In: 14th IFAC Symposium on Information Control Problems in Manufacturing, 2012.
- **B. Vogel-Heuser et al.:** Model-driven Engineering of Manufacturing Automation Software Projects – A SysML-based Approach. Mechatronics, vol. 24, pp. 883-897, 2014.
- **D. Schütz et al.:** Development of PLC-based Software for Increasing the Dependability of Production Automation Systems. IEEE Transactions on Industrial Informatics, vol. 9, pp. 2397-2406, 2013.
- **S. Ulewicz et al.:** Flexible Real Time Communication between Distributed Automation Software Agents. 22nd International Conference on Production Research (ICPR 2013), Iguassu Falls, Brazil. 2013.
- **C. Legat, J. Folmer, B. Vogel-Heuser:** Evolution in Industrial Plant Automation: A Case Study. 39th Annual Conference of the IEEE Industrial Electronics Society (2013), Vienna, Austria.
- **B. Vogel-Heuser, C. Legat, Folmer J., and S. Rösch:** Challenges of Parallel Evolution in Production Automation Focusing on Requirements Specification and Fault Handling. at – Automatisierungstechnik, Vol. 62, Nov. 11, 2014.
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