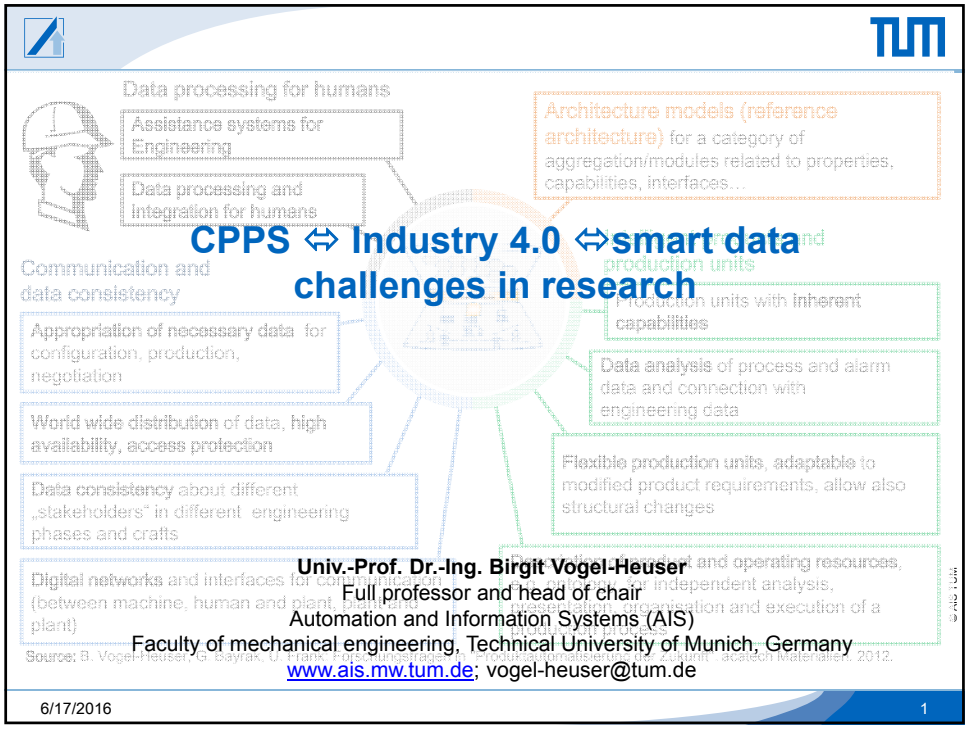


CPPS ⇔ Industry 4.0 ⇔smart data challenges in research

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

Institute of Automation and Information Systems (AIS)

Memberships

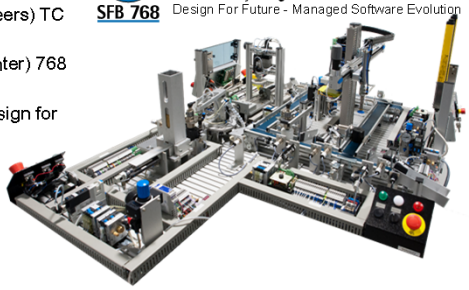
- Chair of VDI/VDE (Association of German Engineers) TC 5.15 "Multi-Agent Systems in Automation"
- Coordinator of CRC (Collaborative Research Center) 768 "Managing cycles in innovation processes"
- Co-Initiator of PP (Priority Programme) 1593 "Design for Future – Managed Software Evolution"

Scientific staff

- 3 Post Docs
- ca. **15** PhD students
- **9** technicians, trainees (software engineering)

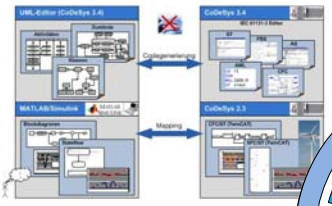
SFB 768

Design For FUTURE
DFG Priority Programme 1593
Design For Future - Managed Software Evolution

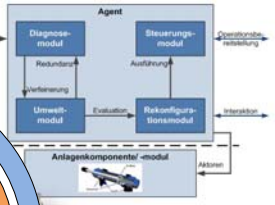


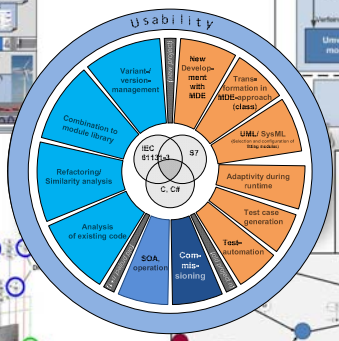
Research Topics

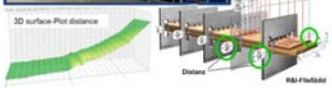
Model-Driven Development

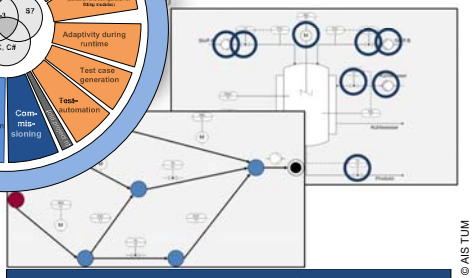


Intelligent Distributed Systems









Smart Information

Big Data in aPS

Industrie 4.0 bietet die folgenden Eigenschaften

There are still several definitions of Industrie 4.0 (I4.0). Most of them agree on the following design principles [1]: https://en.m.wikipedia.org/wiki/Industry_4.0 (accessed 27th January 2016)

- Service Orientation: CPPS offering services via the Internet based on a service oriented reference architecture,
- intelligent self-organizing CPPS providing
- the ability of CPPS to make decisions on their own (decentralization)
- the ability of CPS, humans and CPPS to connect and communicate with each other (interoperability)
- information aggregation and representation for the human in the loop during engineering and maintenance of aPS
- a virtual copy of CPPS on different levels of detail, e.g. from sensors and actuators to the entire CPPS (virtualization)
- relevant process and engineering information for data analysis (real time capability)
- the ability to flexible adaptation to changing requirements by replacing or expanding individual modules (cross-disciplinary modularity)
- Big Data algorithm and technologies provided in real-time (real-time capability)
- optimization of the manufacturing process based on these algorithms and data to increase Overall Equipment Effectiveness (OEE)
- data integration cross disciplines and along the life cycle based on standardized data models and a model driven modular engineering process
- secure communication enabling a worldwide network of aPS supporting economic industrial partnership across companies borders,
- access to data securely stored in a Cloud/Intranet

Vogel-Heuser, Hess, IEEE TASE 2016

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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

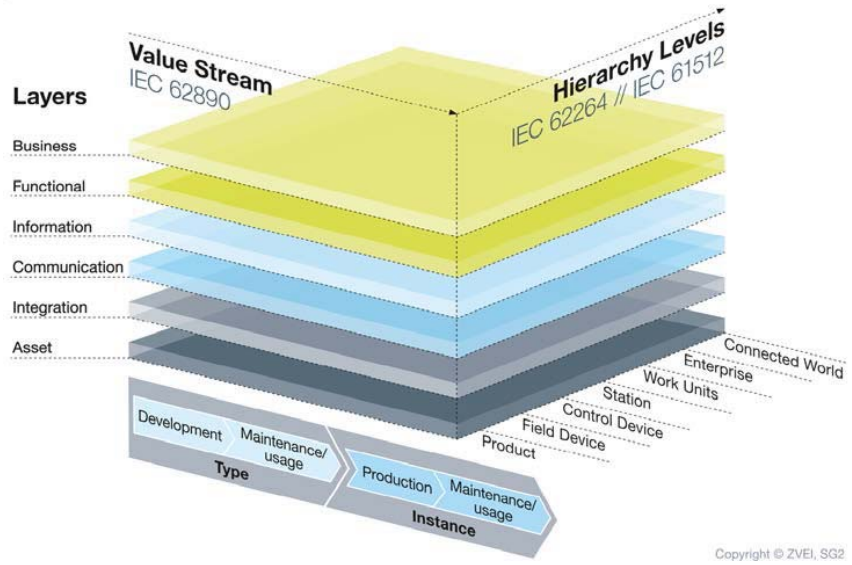
- **Appropriation of necessary data** for configuration, production, negotiation
- **World wide distribution** of data, **high availability, access protection**
- **Data consistency** about different „stakeholders" in different engineering phases and crafts
- **Digital networks** and interfaces for communication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

Reference architecture for Industrie 4.0



Source: VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik: Statusbericht; Industrie 4.0; Wertschöpfungsketten. Düsseldorf: VDI e.V., April 2014.

Characteristics of Industrie 4.0 component based on RAMI 4.0

Identifiability
- Unique identifier in network
- Physical objects are referenced by an ID
- Security
- **Timely Behavior**
- Different address types for I4.0 components and (application) objects

Virtual Description
Virtual representation (including dynamic behavior)

Security and Safety
- Protection for functionality and data (Security)
- Machine safety (Safety)
- Mindset-infrastructure security by Design (SbD)

I4.0-conform Semantics
Support semantics standardized for I4.0

State
State can be obtained at any time

Combinability
I4.0 components can be composed to form a bigger component

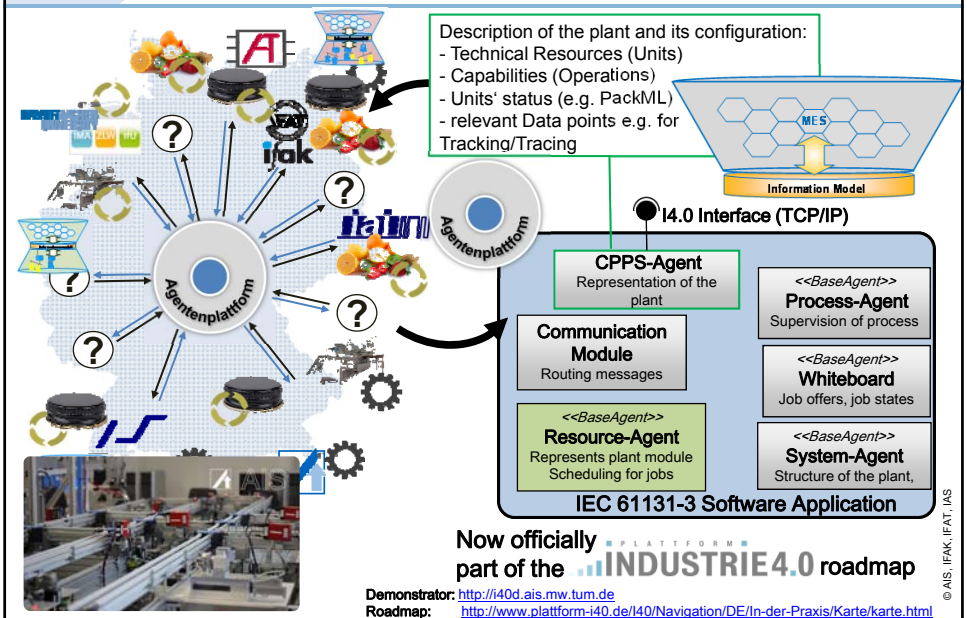
Quality of Service
Satisfaction of required characteristics as e.g. **real-time properties**, **dependability** etc.

I4.0-compliant services and states
- Distinction between shop floor/office floor
- Protocols and application functions can be updated/ extended
- Application layers with different protocols

I4.0-conform communication
Self-identification (SOA-Service model)

Source: VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik: Statusbericht; Industrie 4.0; Wertschöpfungsketten. Düsseldorf: VDI e.V., April 2014.

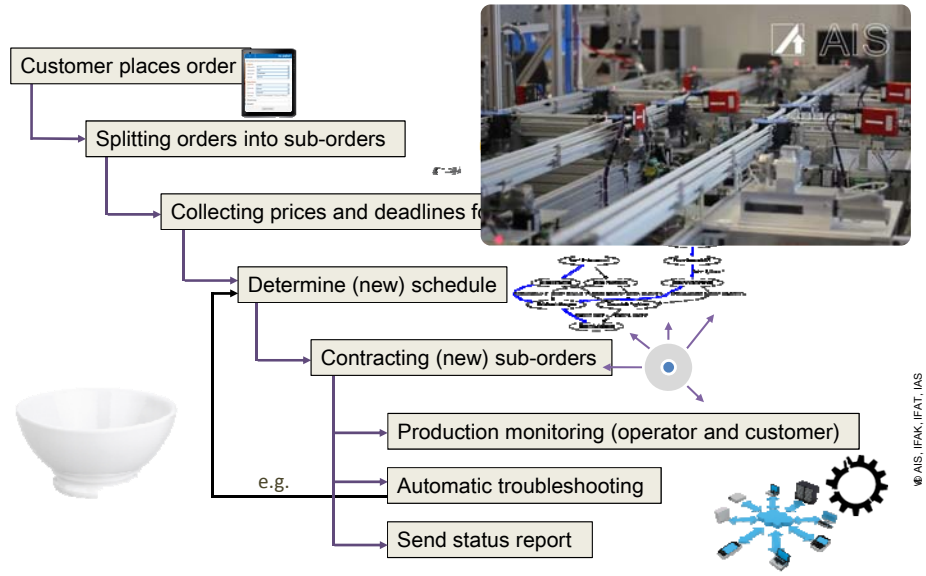
My Joghurt – accepted Industrie 4.0 demonstrator



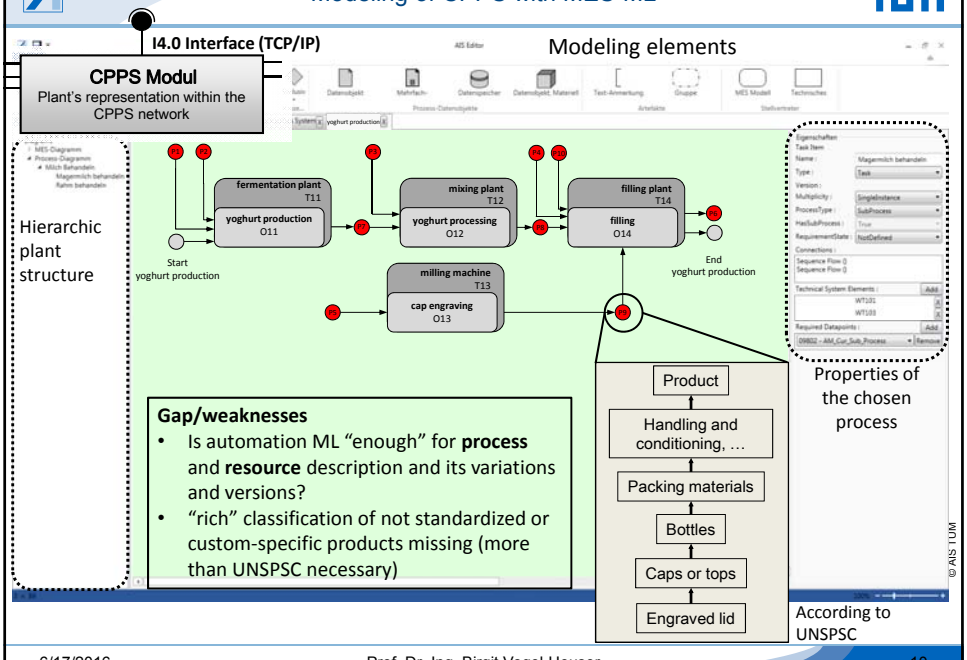
Now officially part of the PLATTFORM INDUSTRIE4.0 roadmap

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

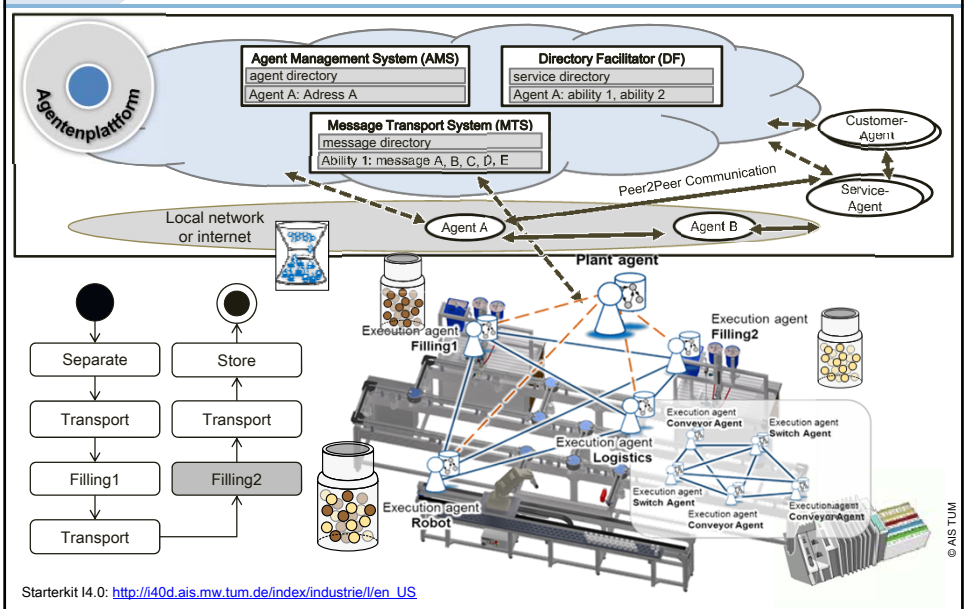
Procedure of production control



Modeling of CPPS with MES-ML



Self-adapatation of an CPPS

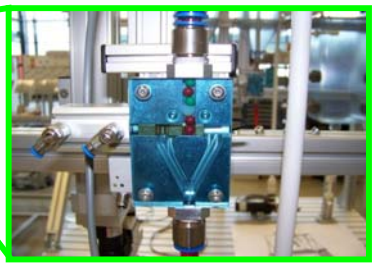


Starterkit I4.0: http://i40d.ais.mw.tum.de/index/industrie/l/en_US

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.

Modeling of Ressource for pellet dispenser

- SystemUnitClassLib
  - Filling station {**Class:**}
    - Tank {**Class: Role:**}
    - Pellet dispenser {**Class: Role:**}
      - Pneumatic cylinder {**Class: Role:**}
        - Interfaces
          - Input Air Extend {**Class:** PortConnector}
          - Input Air Retract {**Class:** PortConnector}
          - Behaviour {**Class:** PLCopenXMLInterface}
      - Case {**Class: Role:**}
        - Interfaces
          - Geometry {**Class:** COLLADAInterface}



<AutomationML/>

- CAEX for structural desciption
- PLCOpenXML for behavioral description
- Collada for geometric description

Input Diameter	
Name	Input Diameter
Description	
Value	8
Default Value	
Unit	mm
DataType	xs:string
Attribute1	
Output 1 Diameter	
Name	Output 1 Diameter
Description	
Value	8
Default Value	
Unit	mm
DataType	xs:string
Attribute1	
Attribute2	
Output 2 Diameter	
Name	Output 2 Diameter
Description	
Value	5
Default Value	
Unit	mm
DataType	xs:string

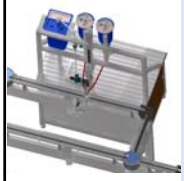
© AIS TUM

Checking attributes of Ressource Model and Product Model with ontologies

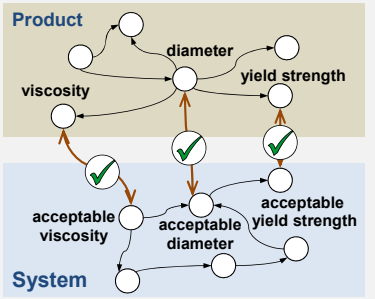
Product description
- **Name**: White chocolate balls
- **Viscosity**: 2.5 Pa*s
- **Yield strength**: 20 Pa
- **Diameter**: 0.5 cm
- **Aggregation state**: solid

Ontology
- Formal knowledge representation
- Provides the means to flexibly process knowledge

→ Basis to identify whether **filler** can manufacture yoghurts with **white chocolate balls**

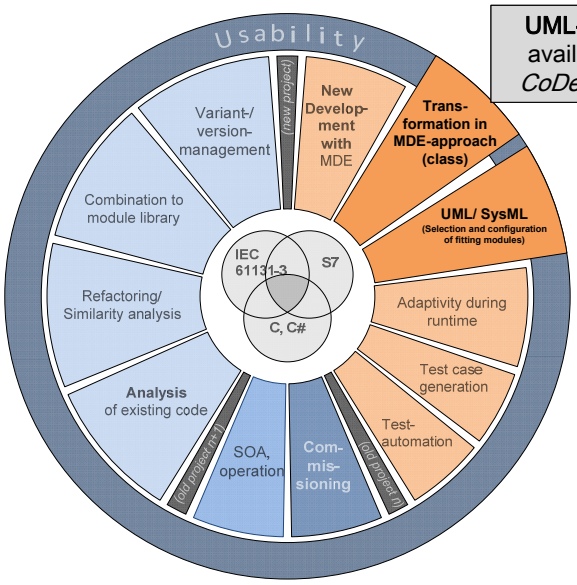


Ressource description
- **Name**: Filler
- **Acceptable viscosity**: 1..3 Pa*s
- **Acceptable yield strength**: 10..30 Pa
- **Acceptable diameter**: 0.2..1 cm
- **Functionality**: separate single solid



Mapping of **technical system**'s characteristics with **requirements from product** and **production process** by means of ontologies

Efficient support of the development process in the machine and plant manufacturing industry



UML-Plugin available in *CoDeSys V3*

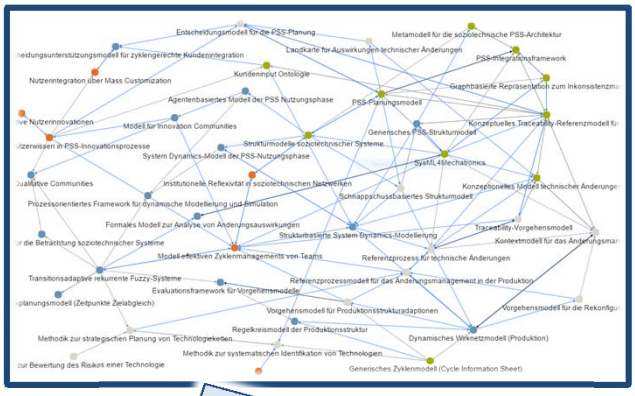
SysML-Plugin available in *TwinCAT*

SysML4Mechatronics

Automatic code system synthesis in intralogistics

Overview on the CRC 768 Model Network

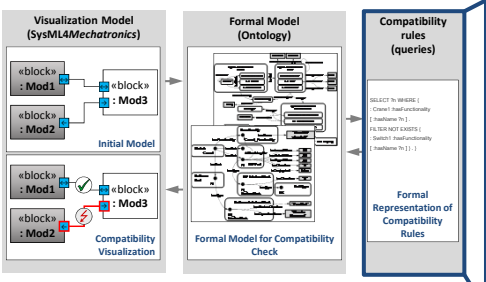
Detailed model information



Picture of the model

Model network including models and relations

Compatibility check through transformation into formal model



- Compatibility rules enable modelling of compatibility criteria based on the component / module-properties
- **Inherent compatibility rules** need to be fulfilled by each model
- **Application-specific rules** extend the framework by further e.g. plant-specific compatibility criteria

Source: Feldmann et al., CIRP CMS, 2014

Compatibility Rules

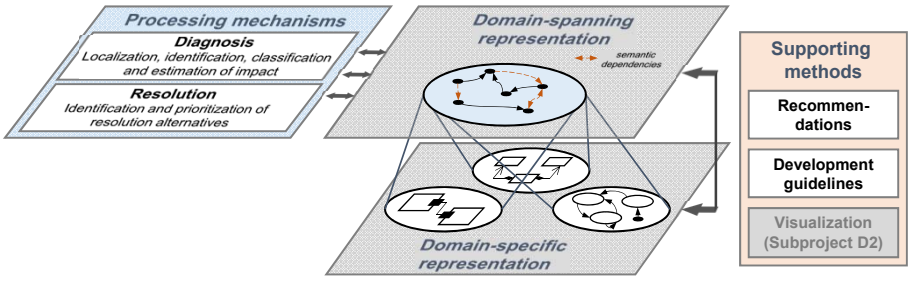
Inherent

- **Data type compatibility:** Same data types
- **Direction compatibility:** In ↔ Out, InOut ↔ InOut, In ↔ InOut, Out ↔ InOut
- **Range compatibility:** Range(In) ≥ Range(Out)
- **Operation:** Same required/ provided operation
- **Port fulfilment:** Mandatory ports must be connected

Application-specific

- Maximum mass
- Maximum energy consumption
- …

SP D1: Diagnosis and resolution of inconsistencies between disparate domain models



Connect
Experience
Comprehend
Visual Computing Laboratory

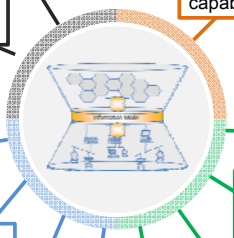
- Basis for development of the approach
  - **Heterogeneous model landscape** of CRC 768
  - **Prioritization of types of models and inconsistencies** together with application and cooperation partners in industry
- Evaluation by means of use cases, empirical evaluation as well as focus groups at the hand of a prototypical realization

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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

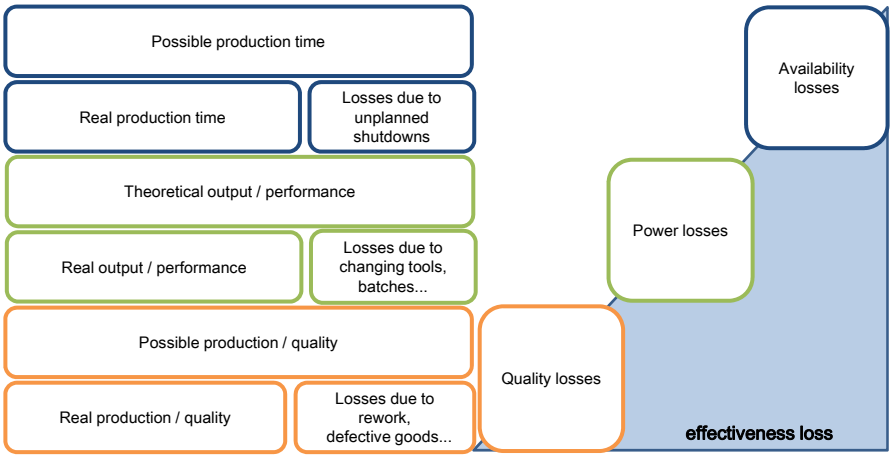
- **Appropriation of necessary data** for configuration, production, negotiation
- **World wide distribution** of data, **high availability, access protection**
- **Data consistency** about different „stakeholders“ in different engineering phases and crafts
- **Digital networks** and interfaces for communication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

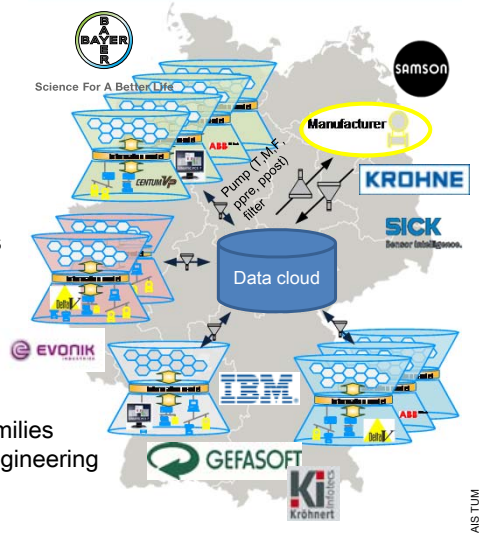
Source: B. Vogel-Heuser, G. Bayrak, U. Frank: Forschungsfragen in "Produktautomatisierung der Zukunft". acatech Materialien. 2012.

Overall equipment effectiveness (OEE)



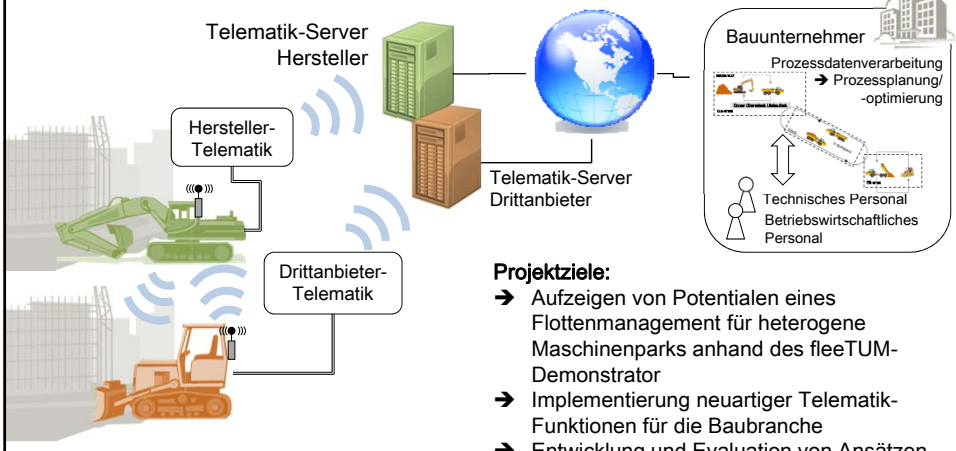
Project: #SmartData2015 / Data Mining in process industry

- 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/

Projekt Bauflott – Entwicklung eines Flottenmanagement zur Prozessunterstützung in der Baulogistik



Projektziele:

- ➔ Aufzeigen von Potentialen eines Flottenmanagement für heterogene Maschinenparks anhand des fleeTUM-Demonstrator
- ➔ Implementierung neuartiger Telematik-Funktionen für die Baubranche
- ➔ Entwicklung und Evaluation von Ansätzen zur Prozessoptimierung mittels Machine-to-Machine (M2M) und Machine-to-Office Kommunikation (M2O)
- ➔ Aufbau einer HiL-Umgebung zur Entwicklung einer Telematikeinheit

Gefördert durch:
Bundesvereinigung Logistik (BVL) e.V. - Projektträger AiF
Projektpartner:
TUM - Lehrstuhl für Fördertechnik Materialfluss und Logistik (FML)
Projektlauftzeit: 01.04.2014 - 31.03.2016
Ansprechpartner: Sebastian Rehberger / rehberger@ais.mw.tum.de

Status AEMP/VDBUM v2.0
Status quo

International Organization for Standardization

Englisch	Deutsch	AEMP v1.2	ISO 15143-3
Equipment information	Identifikation	x	x
Last know location	Letzte bekannte Position	x	x
Cumulative operating hours	Betriebsstunden kumuliert	x	x
Cumulative fuel used	Kraftstoffverbrauch kumuliert	x	x
Fuel used in the preceding 24 hours	*Kraftstoffverbrauch 24h*	x	x
Cumulative distance travelled	Wegstrecke kumuliert	x	x
Cumulative idle operating hours	Leerlaufzeit kumuliert		x
Fuel remaining ratio	*Kraftstoffanzeige*		x
Is engine running	Motor an/aus		x
Digital input state	*Externer Anschluss*		x
Cumulative power take-off hours	Kumulierte Nebenantriebsstunden		x
Average daily engine load factor	*Durchschnittlicher Tageslastfaktor*		x
Peak Daily Speed for past 24 hours	Maximalgeschwindigkeit der letzten 24h		x
Cumulative Load Count	Ladespiele kumuliert		x
Cumulative Payload Totals	Umschlagsleistung kumuliert		x
Cumulative nonproductive regeneration hours	*Regenerationszeit Dieselpartikelfilter*		x
Diagnostic trouble codes	*Fehlercodeübermittlung*		x
Caution code	**Anzeige Warnleuchten im Kombiinstrument**		x
DEF remaining ration	**Anzeige verbleibende AdBlue-Menge**		x
Cumulative idle nonoperating hours	**Leerlaufzeit kumuliert (absoluter Stillstand)**		x

Kursiv: Namens-änderung

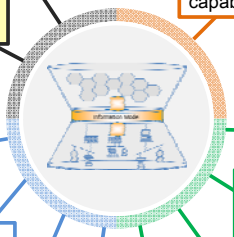
Fett: Neuer Datenpunkt

Cyber-Physical Production Systems (CPPS) – Industrie 4.0

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

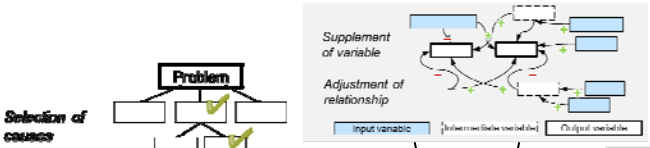
- **Appropriation of necessary data** for configuration, production, negotiation
- **World wide distribution** of data, **high availability, access protection**
- **Data consistency** about different „stakeholders" in different engineering phases and crafts
- **Digital networks** and interfaces for communication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

Intelligent products and production units

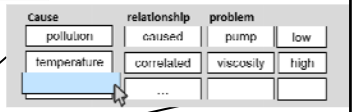
- Production units with **inherent capabilities**
- **Data analysis** of process and alarm data and connection with engineering data
- **Flexible production units**, **adaptable** to modified product requirements, allow also structural changes
- **Description of product and operating resources**, e.g.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

Fleet management and Integration of operator staff



Cause-effect graph



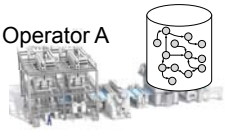
Problem-tree

text blocks

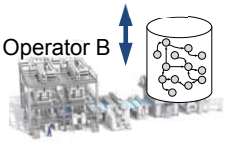
Recordings of operator input → gather existing know-how

Big data

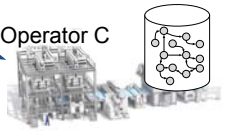
Validation und visualization (AR, Touch)



Operator A



Operator B



Operator C

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

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

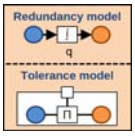
Intelligent products and production units

Reconfiguration, recovery, restart of production units

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

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

SDAP



Production units with **inherent capabilities (learning)**

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

Description of product (classification and ontologies) – consistency checking

MODEMMICAS

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

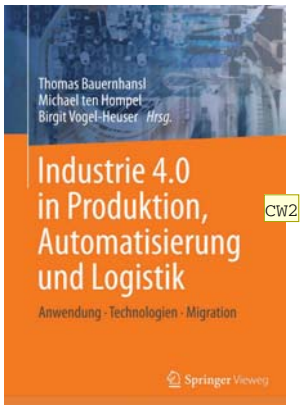
© AIS TUM

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.

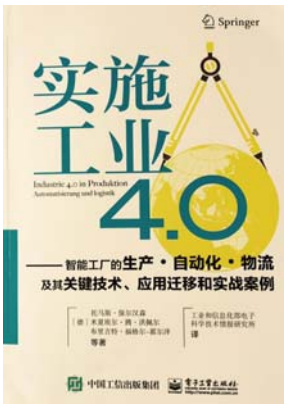
CW3

Industrie 4.0 - References

Print to appear Oct. 2016



CW2



© AIS TUM

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

BV1 ujufm!voe!Bvupsfo!f-
Cjshju!Wphfm.Ifvtfs<!25/15/3127

BV2 Cjshju!Wphfm.Ifvtfs<!25/15/3127

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