Engineering of Automated Systems with Mechatronic Objects

On Cyber Physical Systems, intelligent Units, Industrie 4.0 Components and other granular and decentralized elements in automation engineering

Institute of Industrial Automation Technology and Software Engineering (IAS), University of Stuttgart

Prof. Dr.-Ing. Michael Weyrich
07.07.2014

Institute of Industrial Automation and Software Engineering (IAS); Faculty of Computer Science, Electrical Engineering and Information Technology of Stuttgart University

Research and Teaching of the Institute is focused on software systems for automation engineering and is based on our background in information technology, software and electronics.

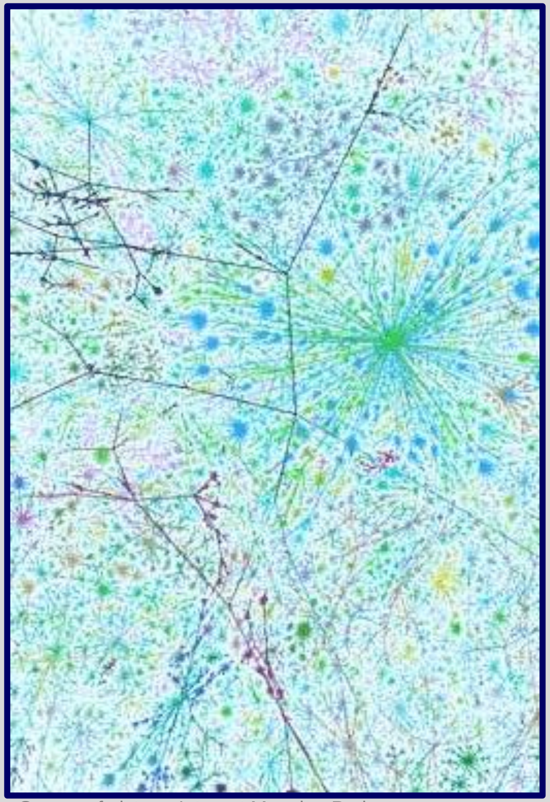
We are researching towards applications of automated manufacturing, automotive and consumers products.

Contents

Contents

- Vision
- State-of-the-Art: Technologies in Automotive
- Research activities
  - Example of Smart Factory and Agent-based control
  - Identification of Mechatronic Objects
  - Moving Design to Runtime
- Conclusion

Vision: Mechatronic Objects / Smart Units / Intelligent Nodes



Source of picture: Internet Mapping Project

Assumption 1: Objects are more and more enabled by means of communication

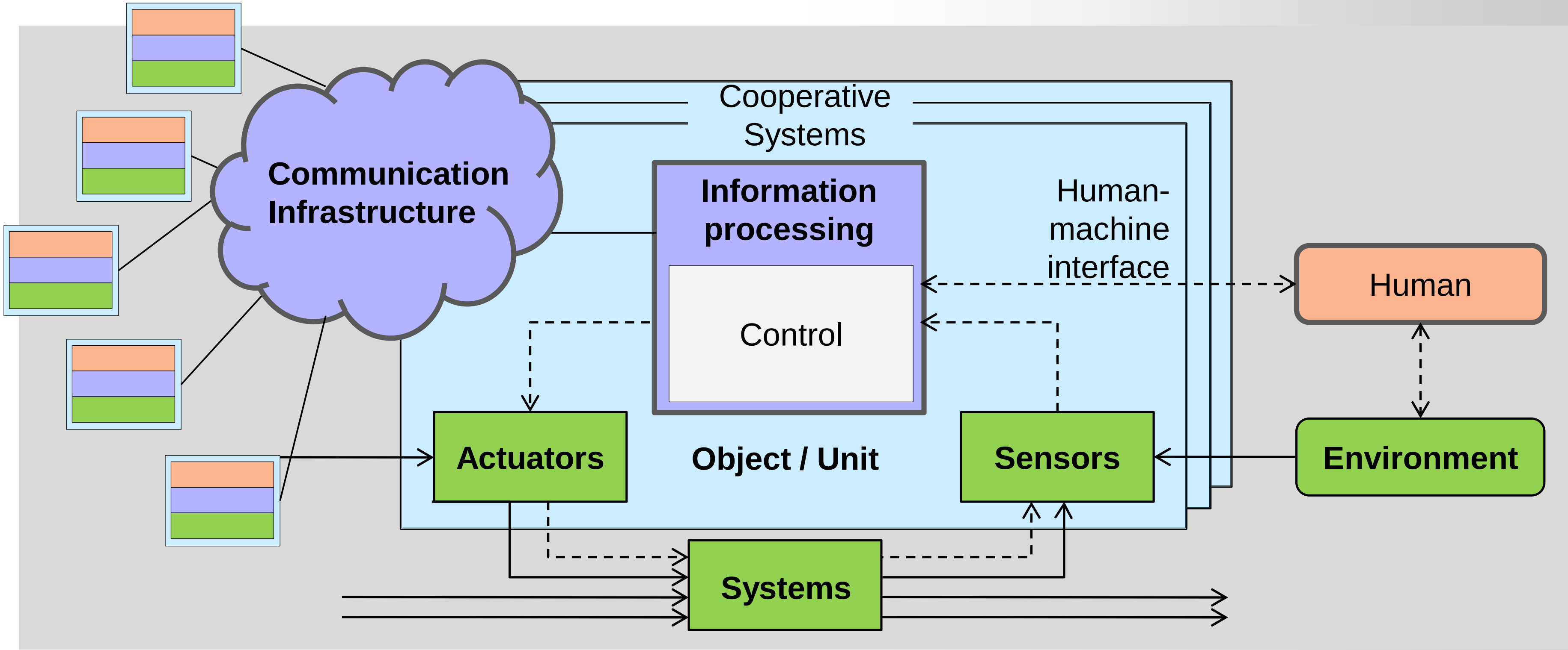
Assumption 2: New services are arising using networked information

Future Trend: The Internet of Things and Services is automating the world.

- Unified interfaces for networking semantics
- Integrated Know-how inside objects
- Configuration instead of development
- Knowledge based Engineering
- Virtual Evaluation
- Functional systems description
- Libraries with basic module / building blocks
- Requirement definition aided by architectural assistant

Mechatronic Objects, Cyber-physical Systems, ...

Smart, networked Systems as a game-changer: New ways of cooperation among distributed and intelligent units.
Interaction with human in a hybrid reality.



Source: Based on : Gausemeier, Univ. Paderborn

Contents

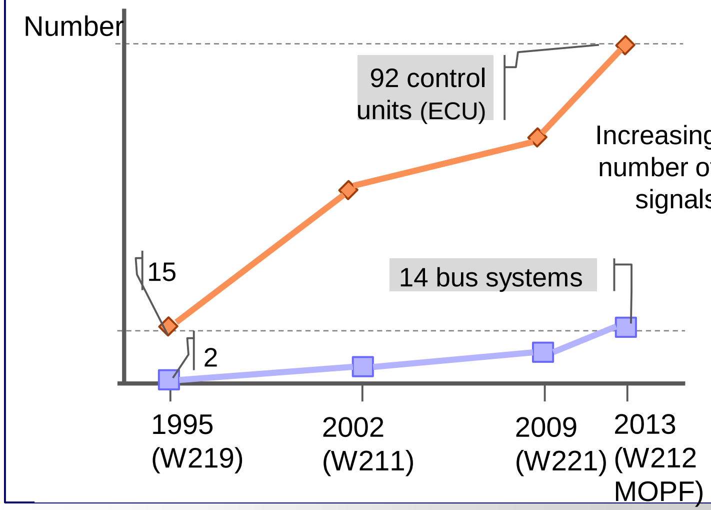
- Vision
- State-of-the-Art: Technologies in Automotive
- Research activities
  - Example of Smart Factory and Agent-based control
  - Identification of Mechatronic Objects
  - Moving Design to Runtime
- Conclusion

Networking Technology of the Car changes the process of Development

- The number of ECU (Electronic control units), signals and bus systems is increasing
- Complexity of Electric / Electronics and software increases due to driver assistant systems and connected cars

- Process improvement and quality management in development (AUTOSAR Standard)
- Model-based development and simulation (SiL, HiL)

Example Daimler (E class)



Source of pictures: Daimler AG

Contents

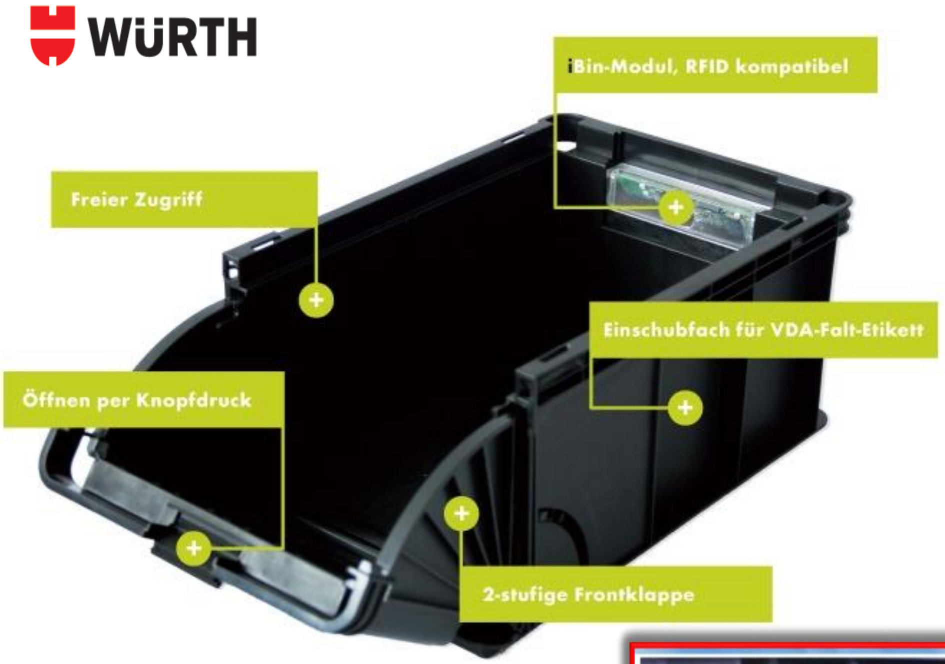
- Vision
- State-of-the-Art: Technologies in Automotive
- Research activities
  - Example of Smart Factory and Agent-based control
  - Identification of Mechatronic Objects
  - Moving Design to Runtime
- Conclusion

Examples for Smart Units

"Smart Units" are conceived by engineers and dedicated towards special application thereby fulfilling a particular customer value

„Intelligent Bin" requests for a refill on its own

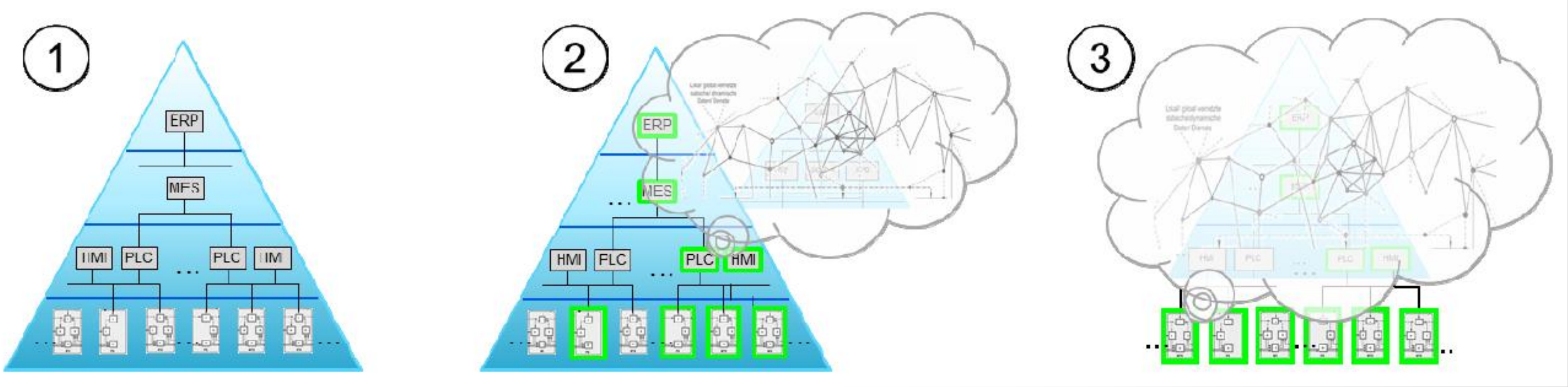
- iBin is counts the parts using an integrated camera
- The system interacts with the Cloud for part logistics



Source: Fraunhofer IML, Prof. Dr. Michael ten Hompel

(Partial) Decentralization of the Architecture

- The level structure in automation (so-called automation pyramid) is dissolving
- Decentralized services are self-organizing and any hierarchy becomes blurred
- Real-time Systems remain however for some time on the bottom field level in the close future



Source: VDI, Hypotheses and fields of action: Opportunities form the perspective of automation technology, April 2013

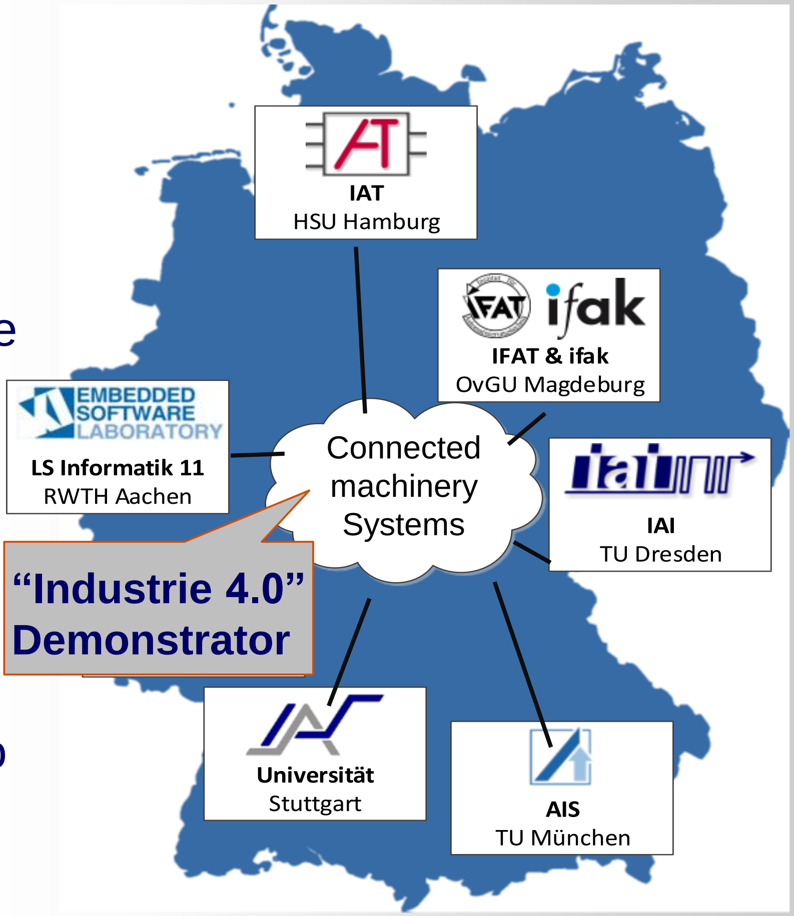
Case Study: “Industrie 4.0” Demonstrator

Cooperation between university institutes of the Automation Community

Application Scenario “My Yogurt“

- ***Individual Product Configuration:***
  Customers can order various amounts and flavors of yogurt via the internet. The yogurt is produced using different machines nation wide.

- ***Diagnosis of the distributed machinery:***
  In the event of system failure of similar machines, an inquiry can be launched to obtain information on how the incident was resolved at another system. This approach can also be deployed for preventive maintenance.



Scource: [Christian Diedrich, OvGU]

Case Study: What is special?

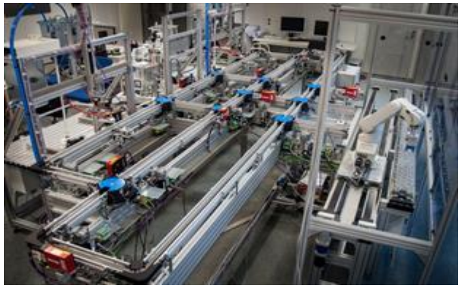
Requirements

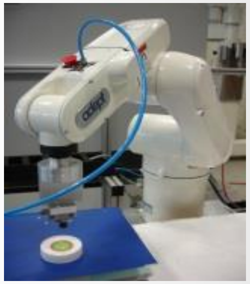
- Configuration of products with interactive resource allocation
- Diagnosis to improve reliability
- Reliable and easy to use by operators
- Re-configurable in the sense of interoperability, adaptivity and ad-hoc cooperation

Technology

- Scheduling, Modelling of Processes
- Apps for human machine communication
- Service-oriented Architecture
- Network Management - Web Based Enterprise Management
- Cloud-Services for validation of embedded systems

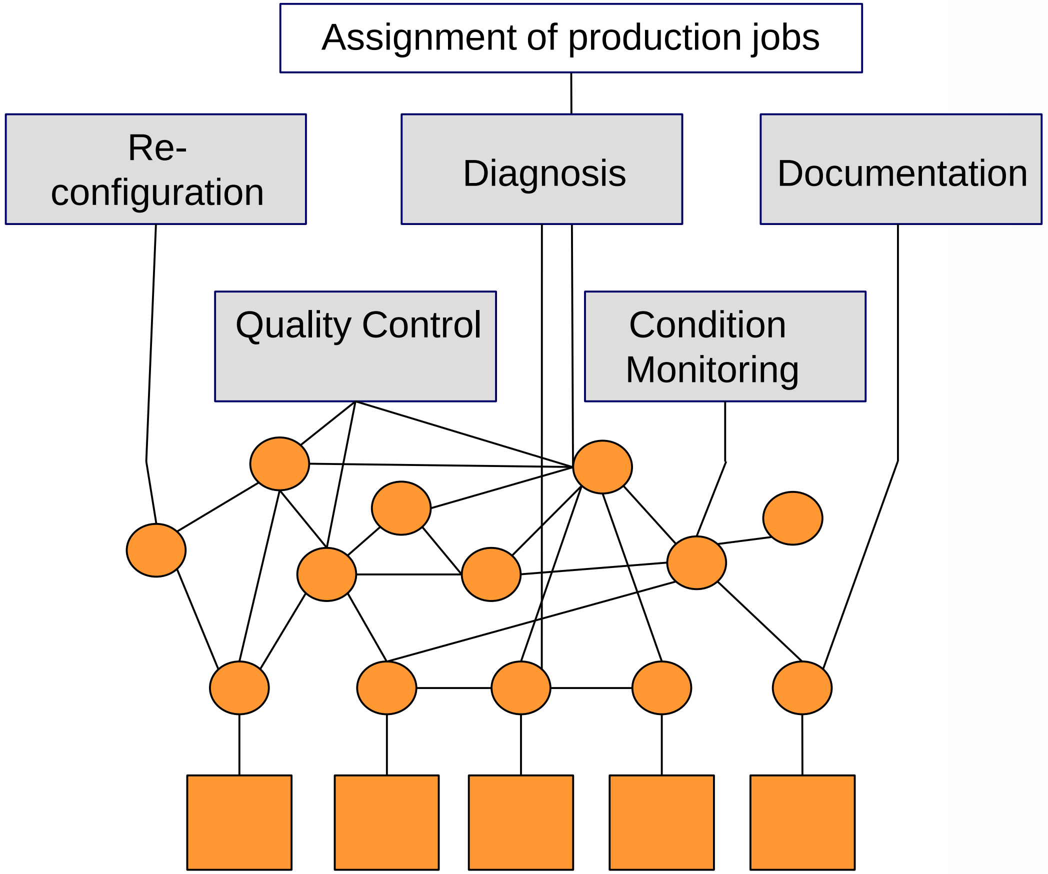
Scource: [Christian Diedrich, OvGU]




Decentralization of Architecture

- Hierarchies are fading and borders become blur
- Decentralized services are partially self-organised by agents



Services for human machine Communication (Apps)

Coordination layer:
Agents with directory of services and data processing

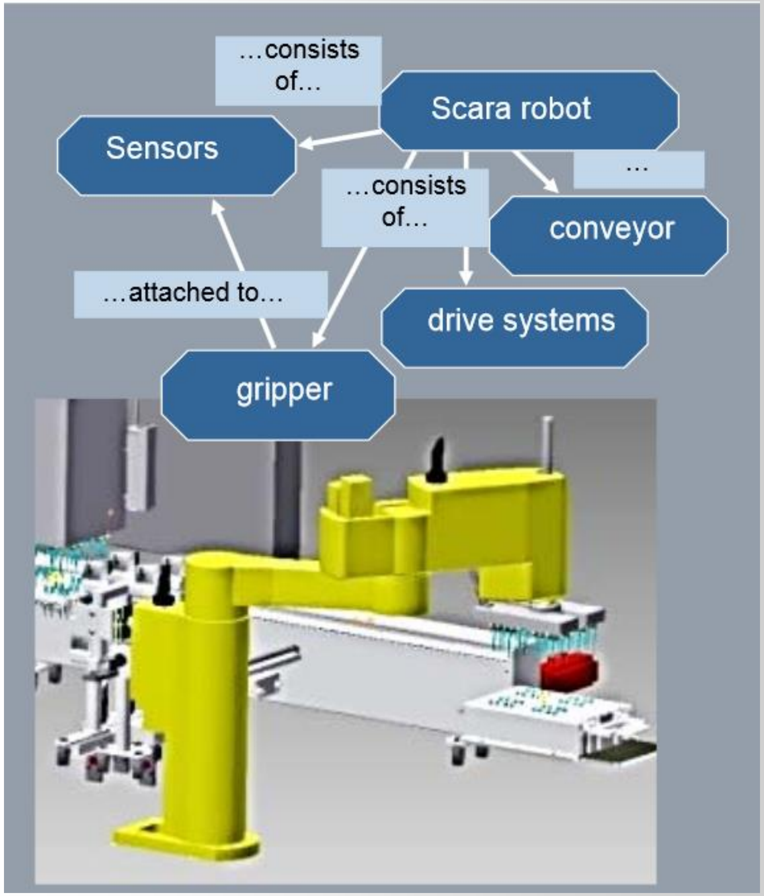
Field Level (Real time level):
Process Control, Sensors, Actuators etc.

Contents

How to identify the Modules?

Top-down analysis of existing systems to identify base elements of existing systems

- Consideration of the domian‘s mechanical design, electronics and software
- Modules should fulfill a defined functionality
- Products or de-facto standardized subsystems which are efficient and well evaluated



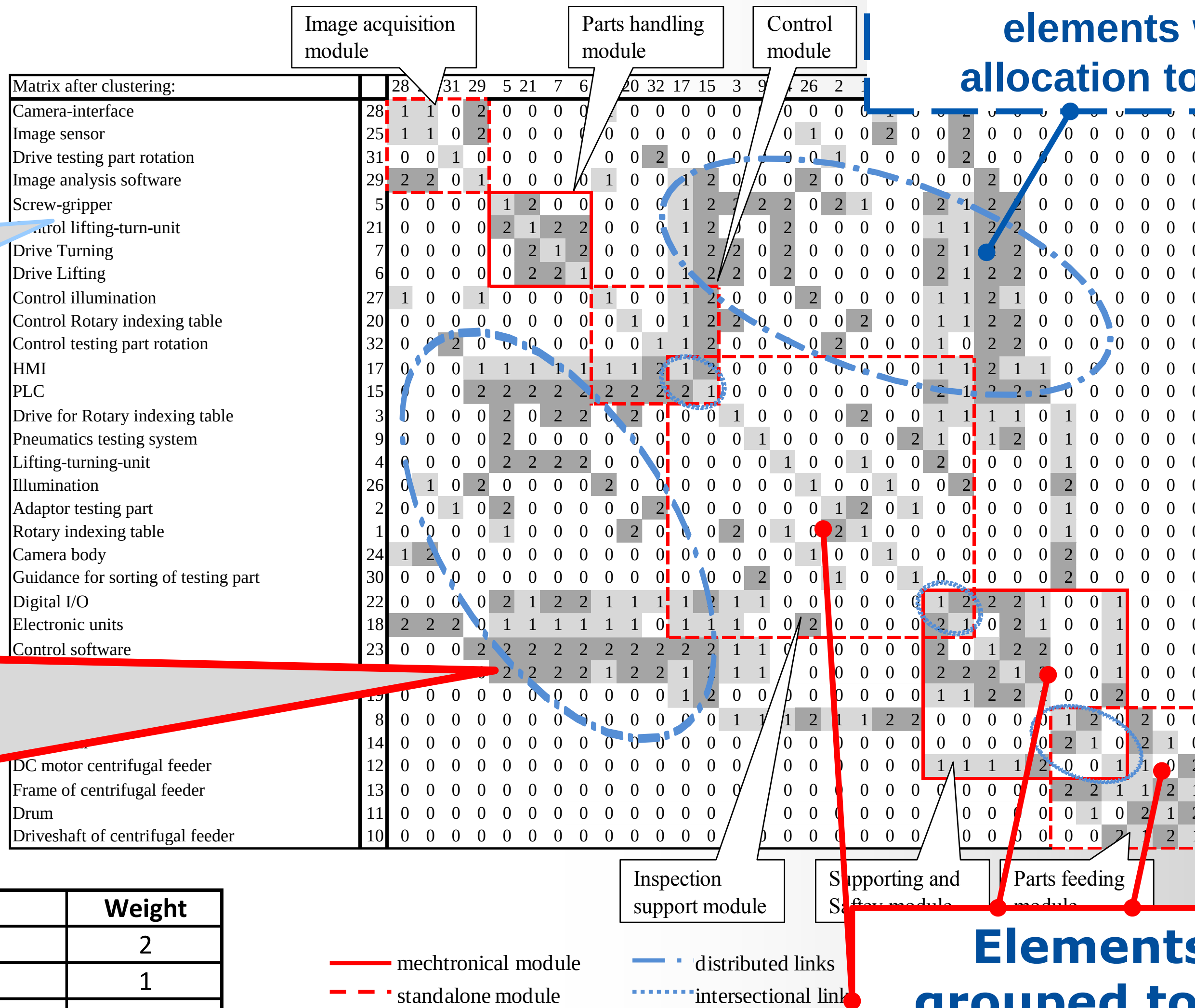
Identification of Modules using the Design Structure Matrix (DSM)

Interfaces are related to elements without allocation to modules

Elements

Small units e.g. from a bill of materials

Is this component depended to the other component to fulfill a function?

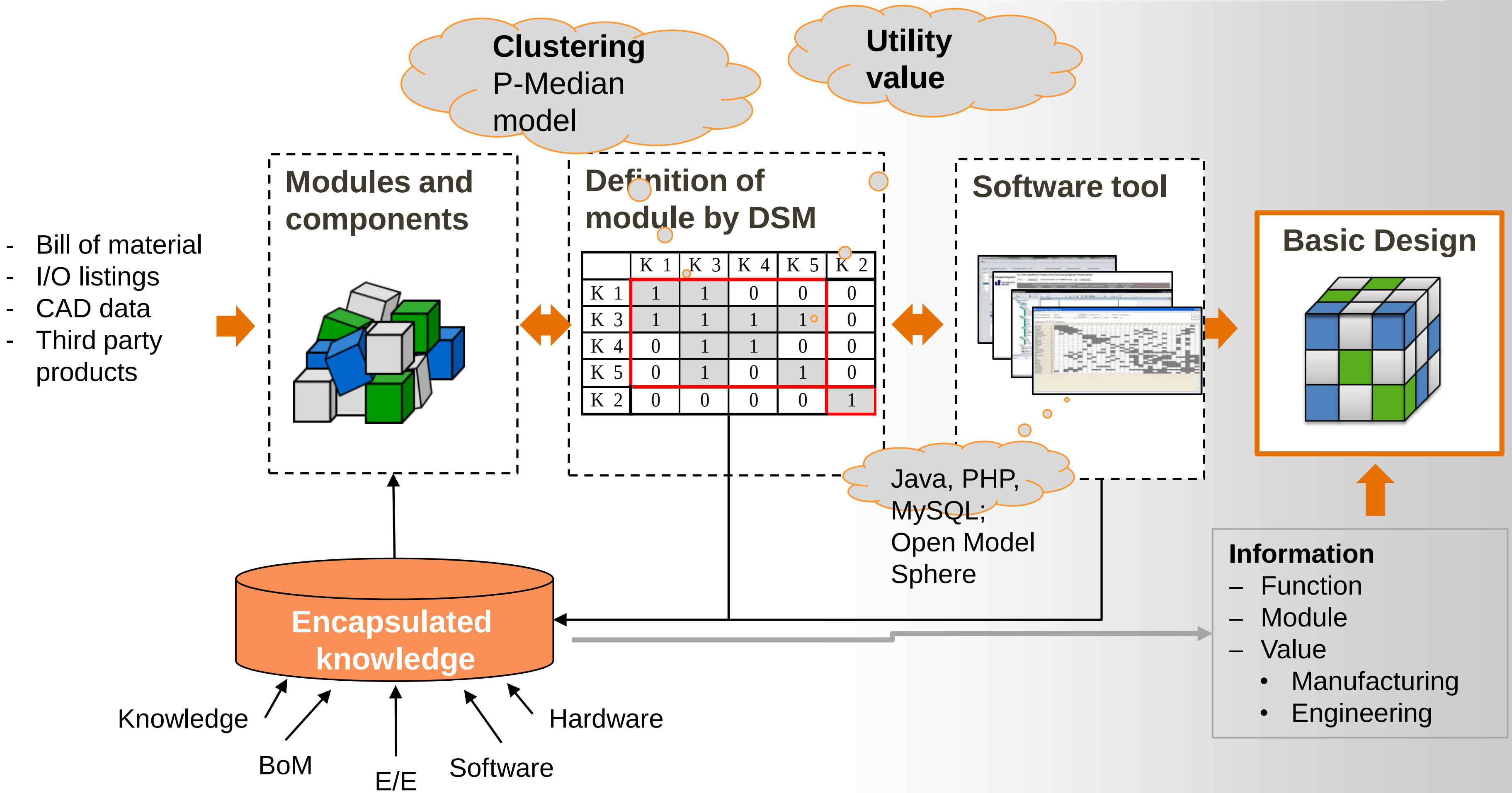


Elements are grouped together as modules

Interaction	Weight
Required	2
Desired	1
Indifferent	0

Modularization for Engineering

A Web-Tool is available for data processing, clustering and value analysis



	K 1	K 3	K 4	K 5	K 2
K 1	1	1	0	0	0
K 3	1	1	1	1	0
K 4	0	1	1	0	0
K 5	0	1	0	1	0
K 2	0	0	0	0	1

Contents

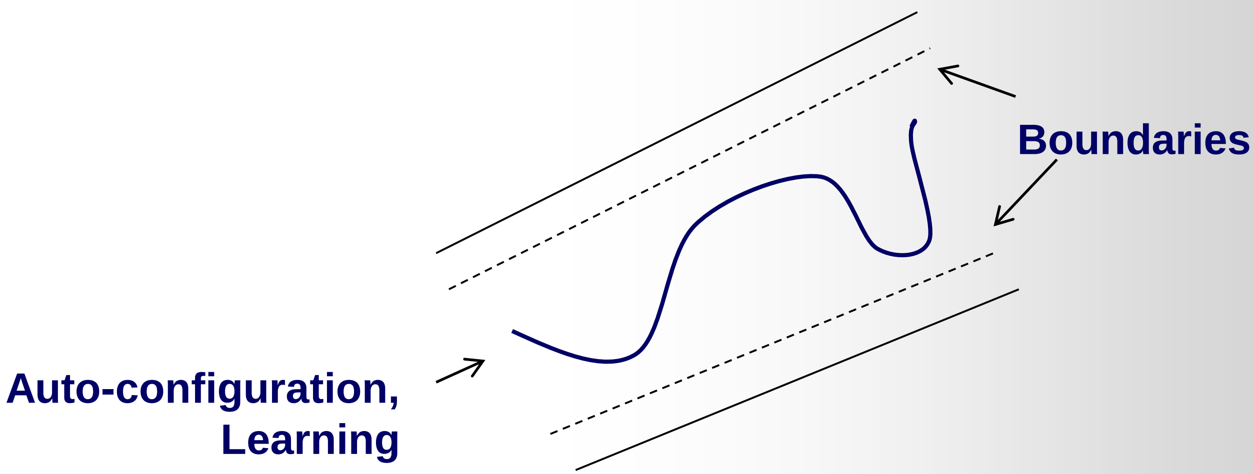
„Moving Design to Runtime"

Smart engineering through learning and self-configuration

Method: Configuration of automation systems through an agent-based Configuration of preconceived Components.
=> Flexible and Re-configurable

Challenge of learning from the perspective of the engineer

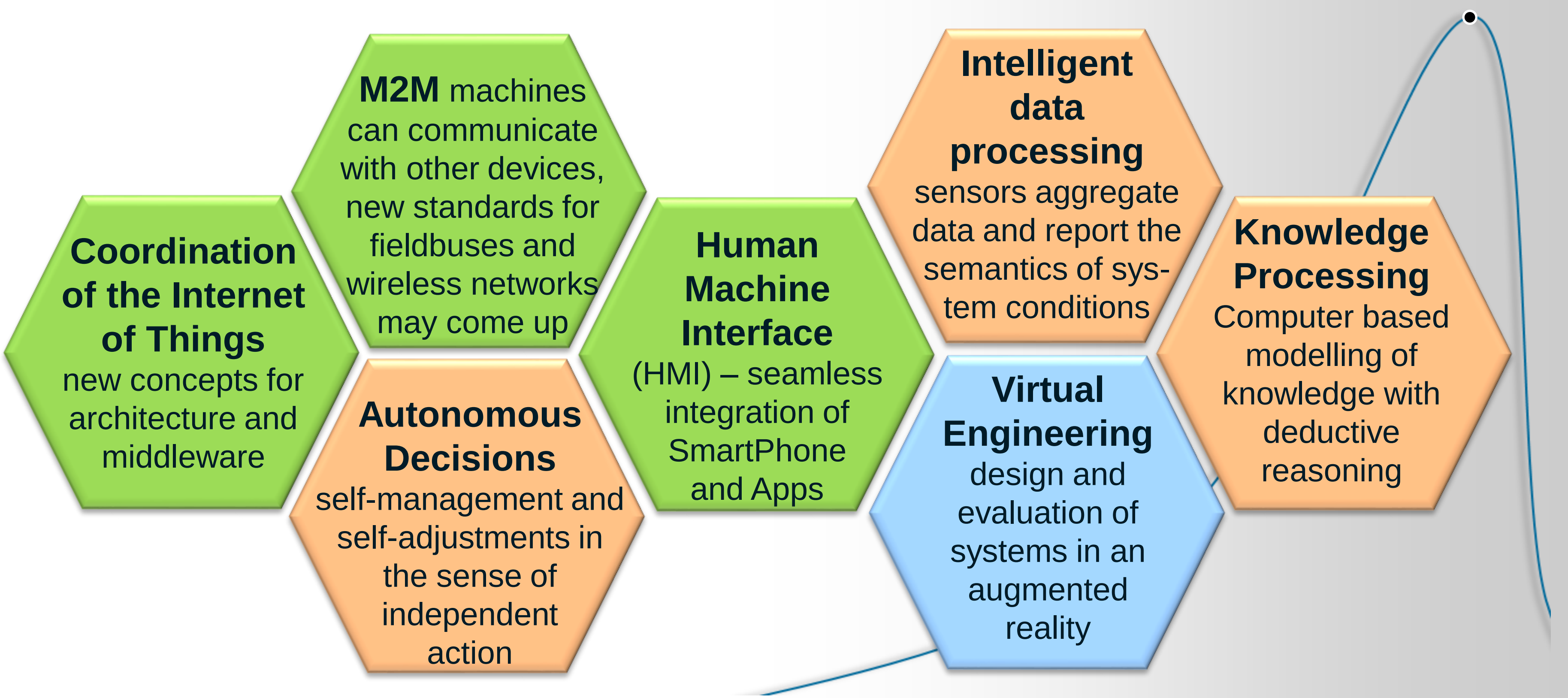
- Keep system compliant with changing requirements



Contents

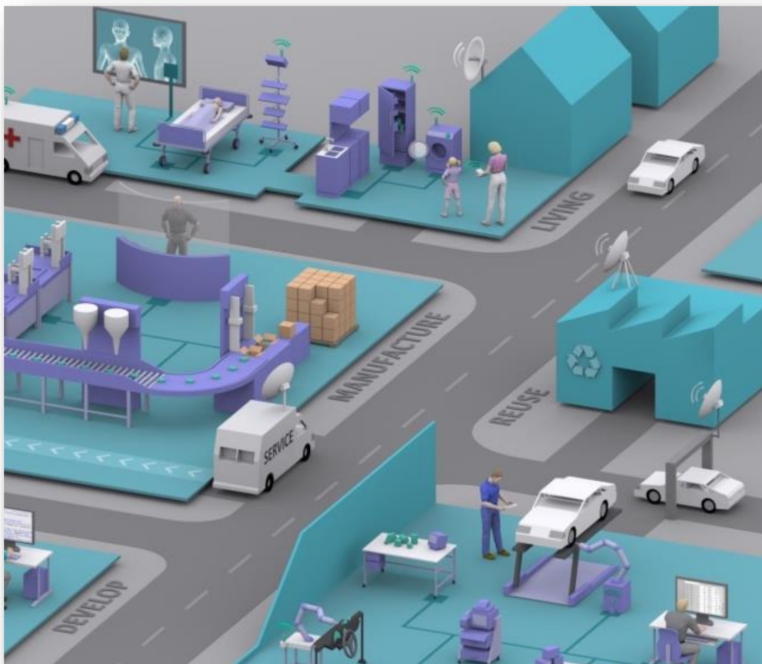
Seamless integration of Automation Technology

Information technology has reached a stage from which disruptive changes of existing paradigms can be expected



Research (…@IAS)

Revolving around the application domain



Leading questions:

- **How to compose automated systems effectively?**
  - Control of Decentralized Systems / Multi-agent systems as a control paradigm
  - Identification methodologies for new Mechatronic Objects
  - Adaptation and learning

- **How to ensure dependability and safety of systems?**
  - Evaluation, Test of systems (level of maturity etc.)