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)

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Abstract: Automation technology has trigged a lot of changes in manufacturing, automotive and urban life. Today we seem to be gradually approaching tipping points which might trigger disruptive innovation in the future.

In automation engineering, many industrial automation systems are configured rather than designed. There is a tendency towards so-called mechatronic objects or intelligent units which are envisioned as building blocks for the design of automation systems. This presentation discusses research questions to identify such objects / units, their configuration and coordination using multi-agent systems.

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.

Resume

- **Education in the area of mechatronics**
  - Studies of Electronic Engineering and Control Engineering at University of Applied Science (Saarbrücken), Ruhr University (Bochum) and University of Westminster (London)
  - Doctorate, RWTH (Aachen) in Mechanical Engineering

- **Daimler**
  - Member of the exchange group research and technology
  - Digital Factory Powertrain and Head of Function CAx Process Chain Production
  - Head of Department Engineering Services, Bangalore (India)

- **Siemens Automation & Drives /Motion Control**
  - Head of Department, direct Report to Head of Business Unit

10 years

- **University Professor**
  - Chair of Manufacturing Automation, University of Siegen
  - Institute of industrial Automation Technology and Software Engineering, University of Stuttgart

5 years

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

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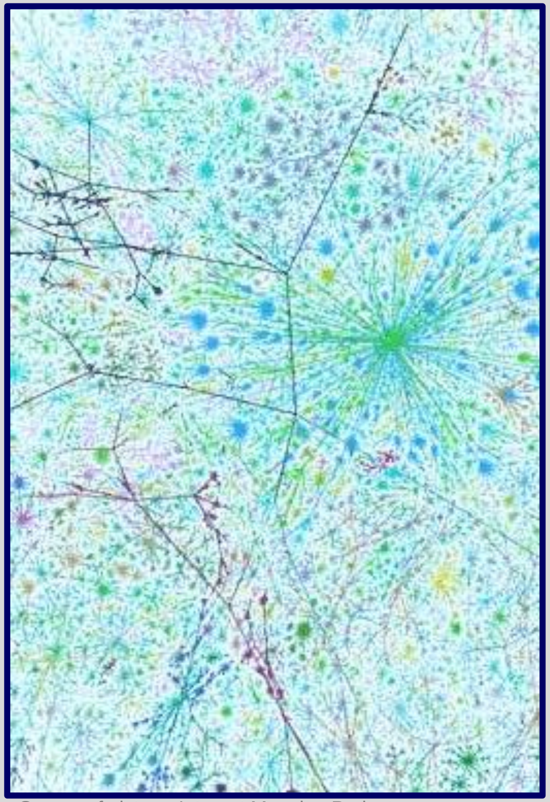
Vision: Mechatronic Objects / Smart Units / Intelligent Nodes



Source of picture: Internet Mapping Project

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

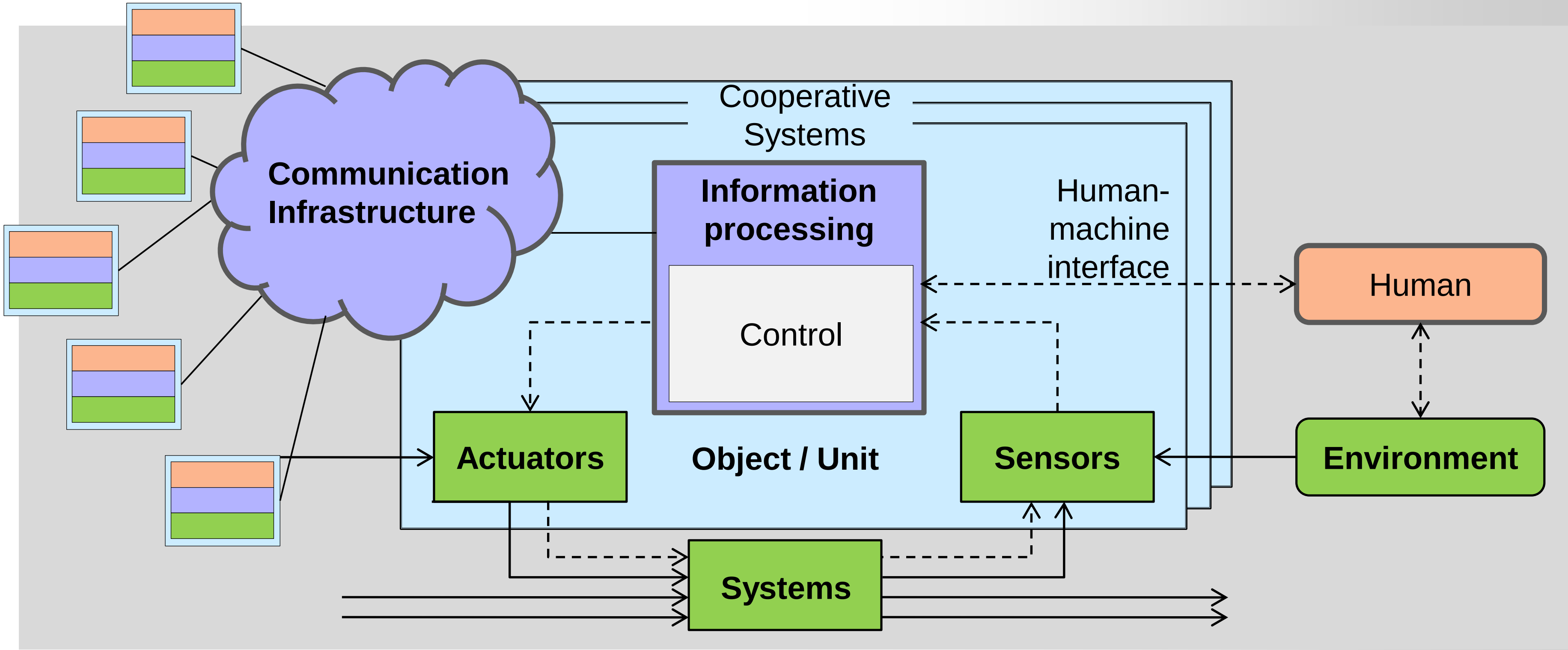
Assumption 2: New services are arising using networked information

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

- Unified interfaces for networking semantics
- Integrated Know-how inside objects
- Knowledge based Engineering
- Configuration instead of development
- 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

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Networking Technology of the Car changes the process of Development

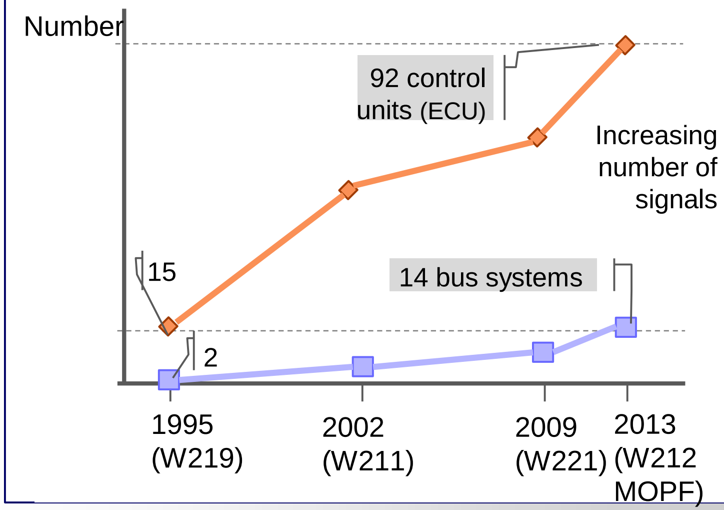
› The number of ECU (Electronic control units), signals and bus systems is increasing

› 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)

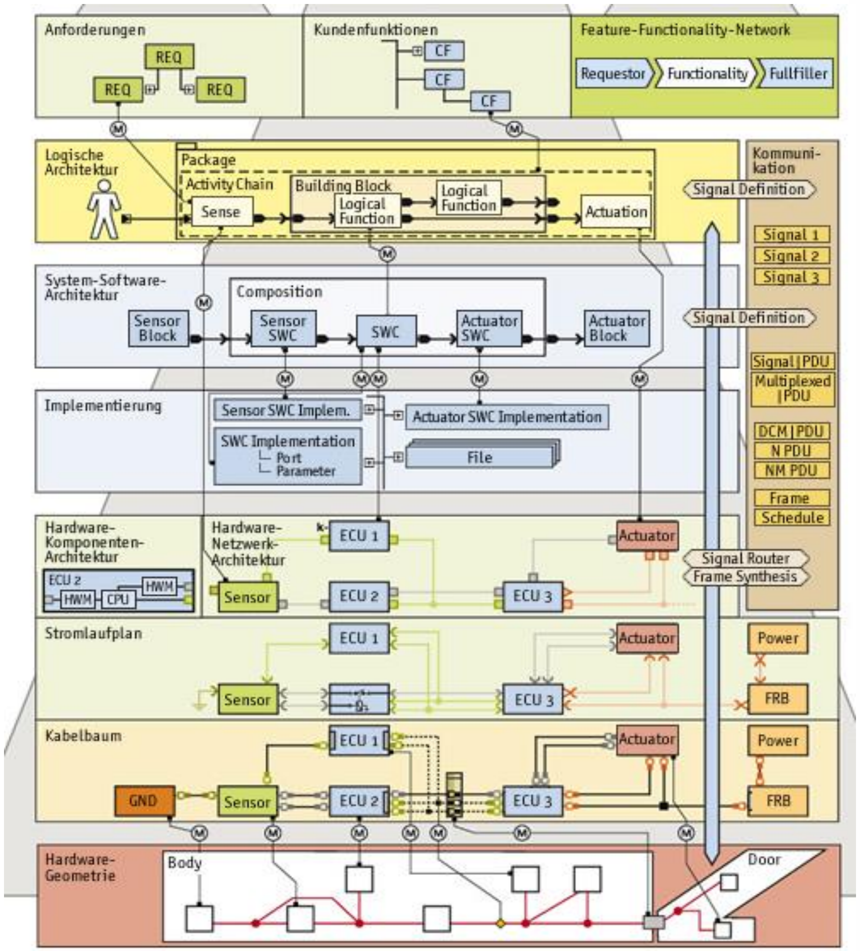
Example Daimler (E class)



Source of pictures: Daimler AG

Example Automotive Software Development

Management of Electric / Electronic and Software Complexity aided by Design Tools



Source of picture: Vector Consulting GmbH

Example of PREEvision modelling tool (Vector Informatics)

Definition of Requirements

Logical structuring into blocks

Design of Software Architecture

Implementation of Software Components

Design of Electric / Electronic Hardware

Development of
- ECUs
- Circuit diagrams
- Wire harness
- Etc.

Hardware Design and spacial distribution

Contents

Examples for Smart Units

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

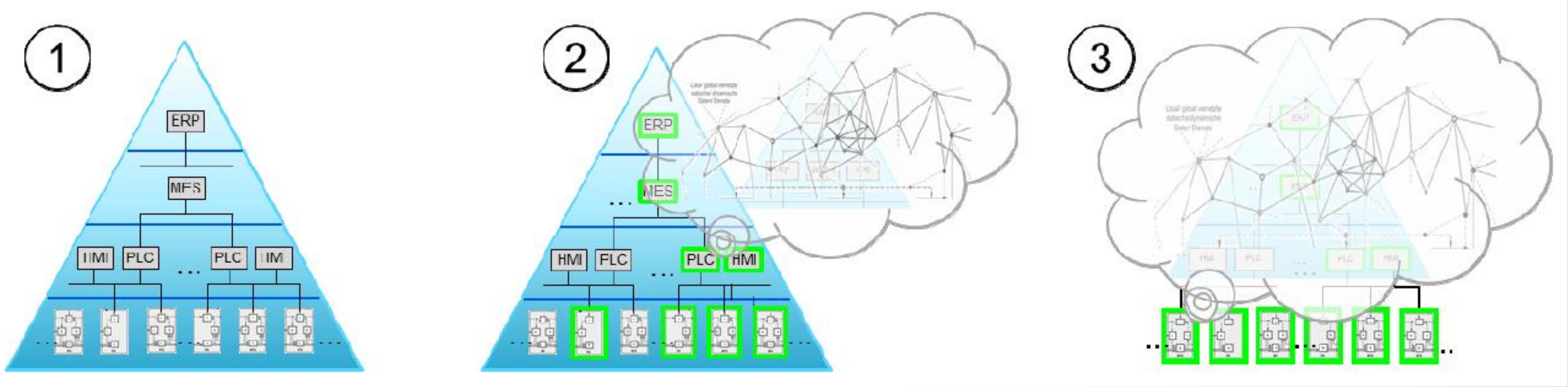
„Intelligent Bin" requests for a refill on its own

- 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

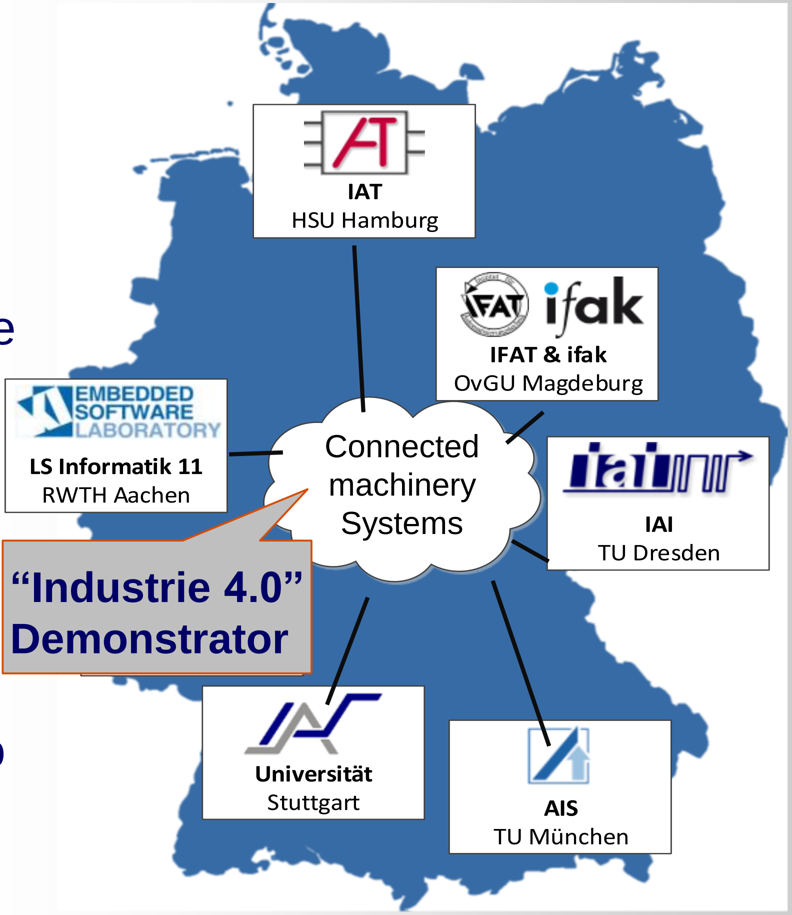
Case Study: "Industrie 4.0" Demonstrator

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.



Source: [Christian Diedrich, OvGU]

Case Study: What is special?

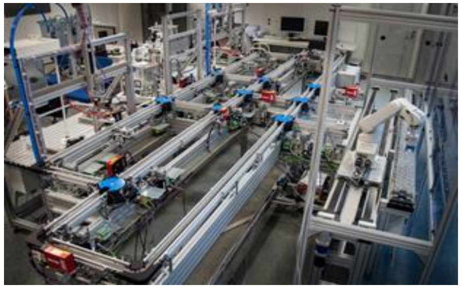
Requirements

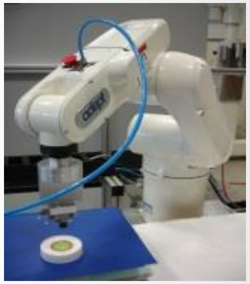
- Configuration of products with interactive resource allocation
- Diagnosis to improve reliability
- Reliable and easy to use by operators
- Re-configurable in the sense of interoperability, adaptivity and ad-hoc cooperation

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]

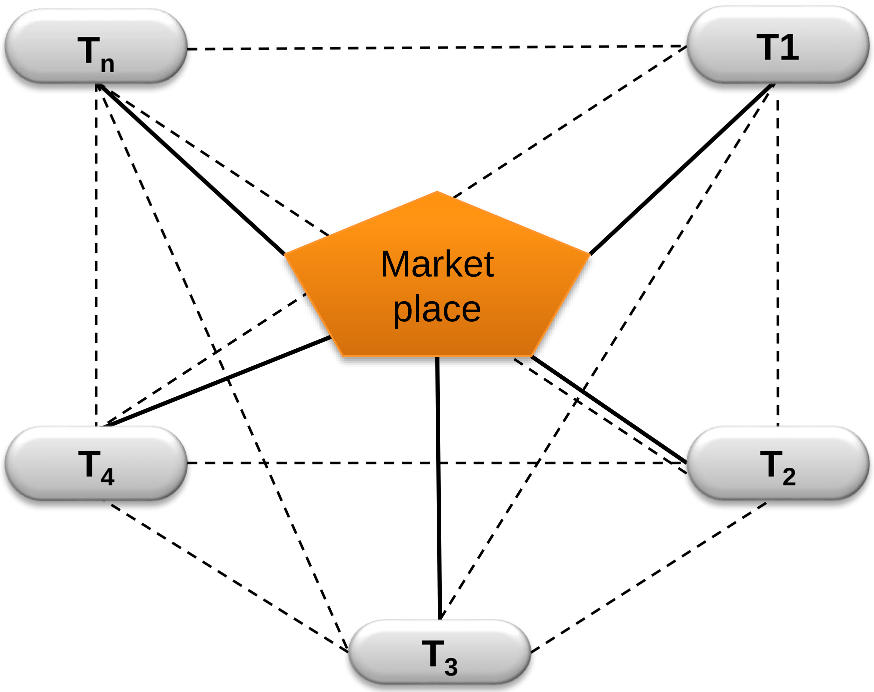



Case Study: Manufacturing Management and Scheduling

Decentral System Topology coordinated by an online marked place concept

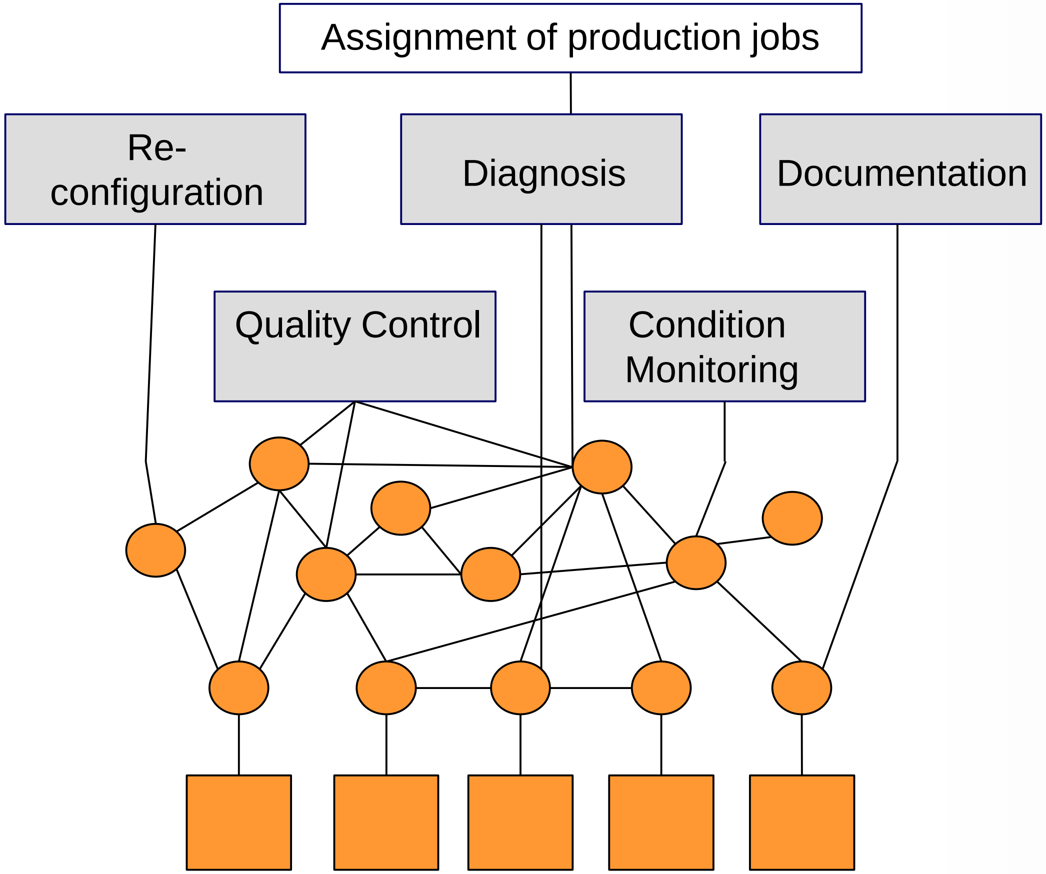
- Scheduling and job distribution
- Resource allocation and subcontracting
- Consideration of special aspects such as energy efficiency
- Quick integration of sub components (I40 Components) into the system



T_1, T_2, … , T_n : dezentral I40 Components

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.

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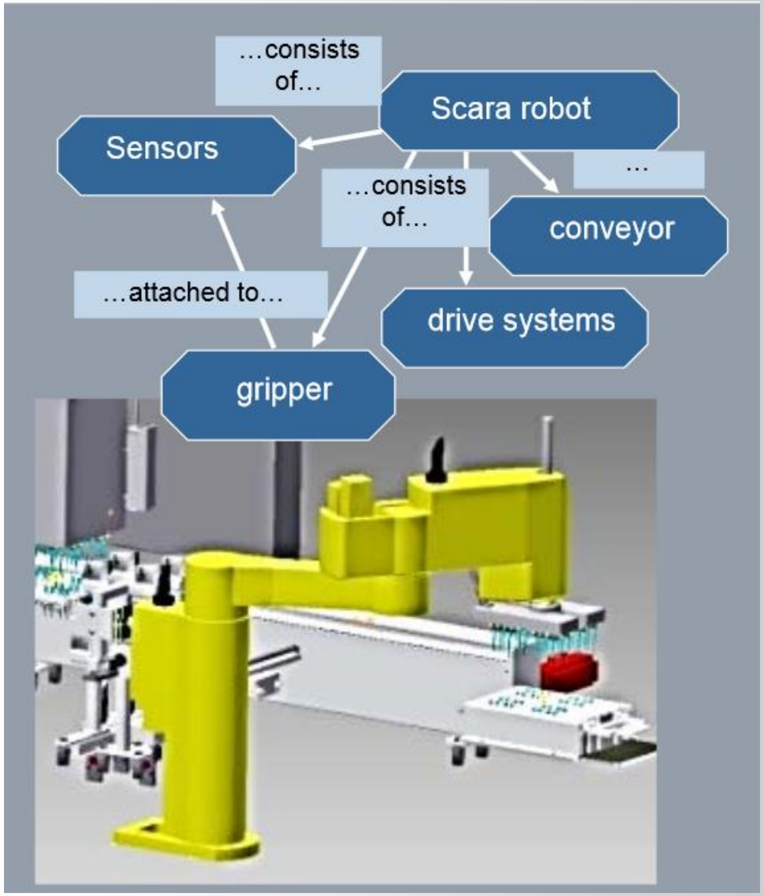
How to identify the Modules?

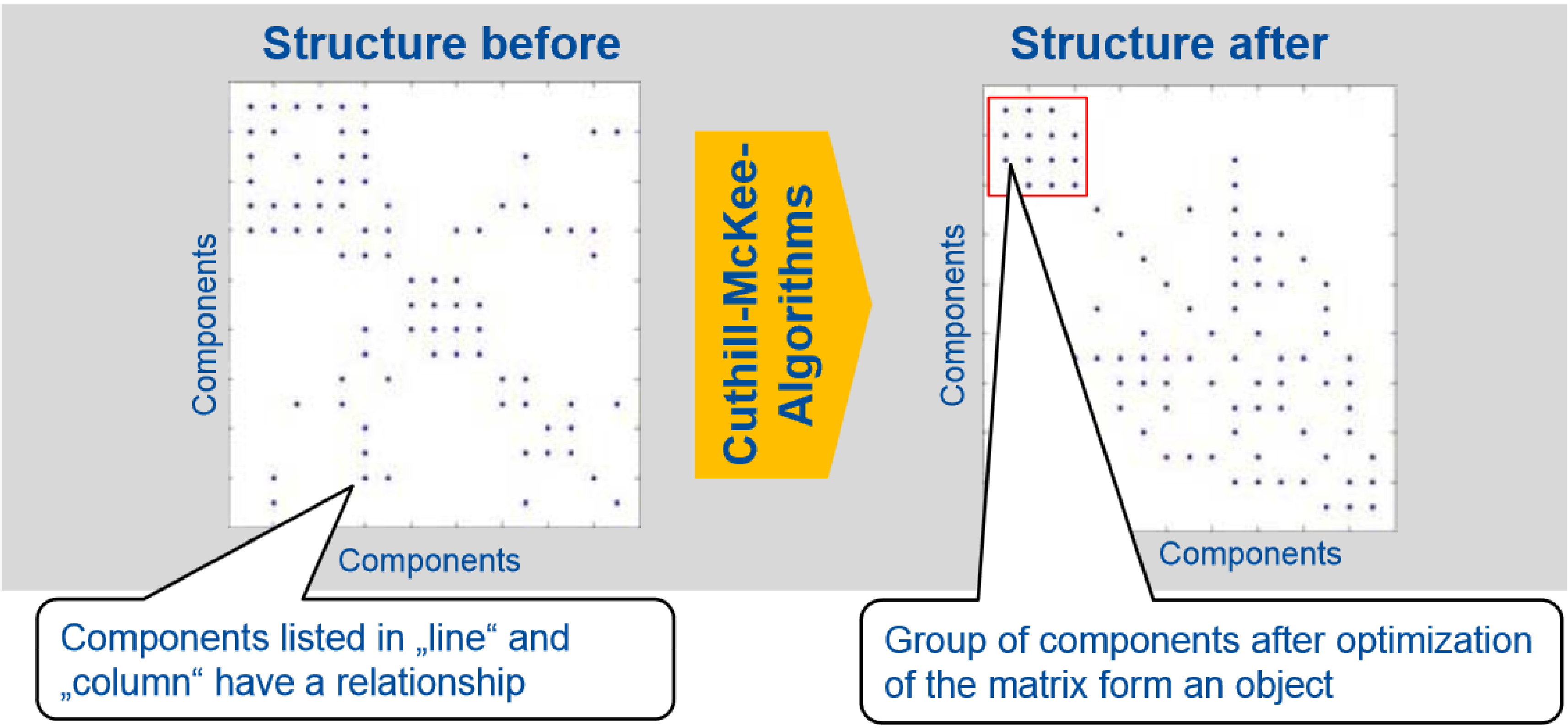
Top-down analysis of existing systems to identify base elements of existing systems

- 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



Grouping by sorting the structure diagonal

Based on the optimized structure of the DSM groups of components, a defined object can be identified.

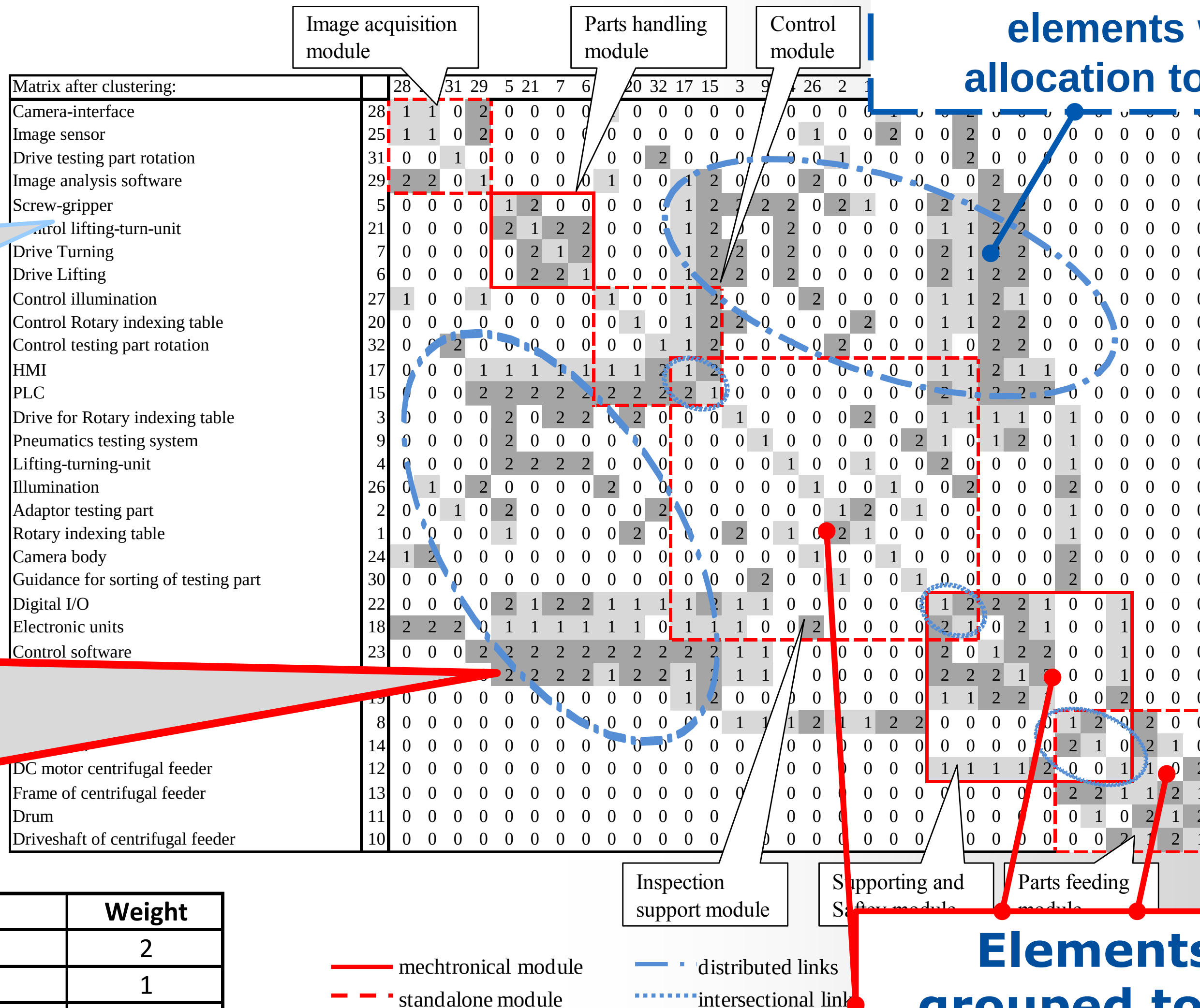


Identification of Modules using the Design Structure Matrix (DSM)

Elements

Small units e.g. from a bill of materials

Interfaces are related to elements without allocation to modules



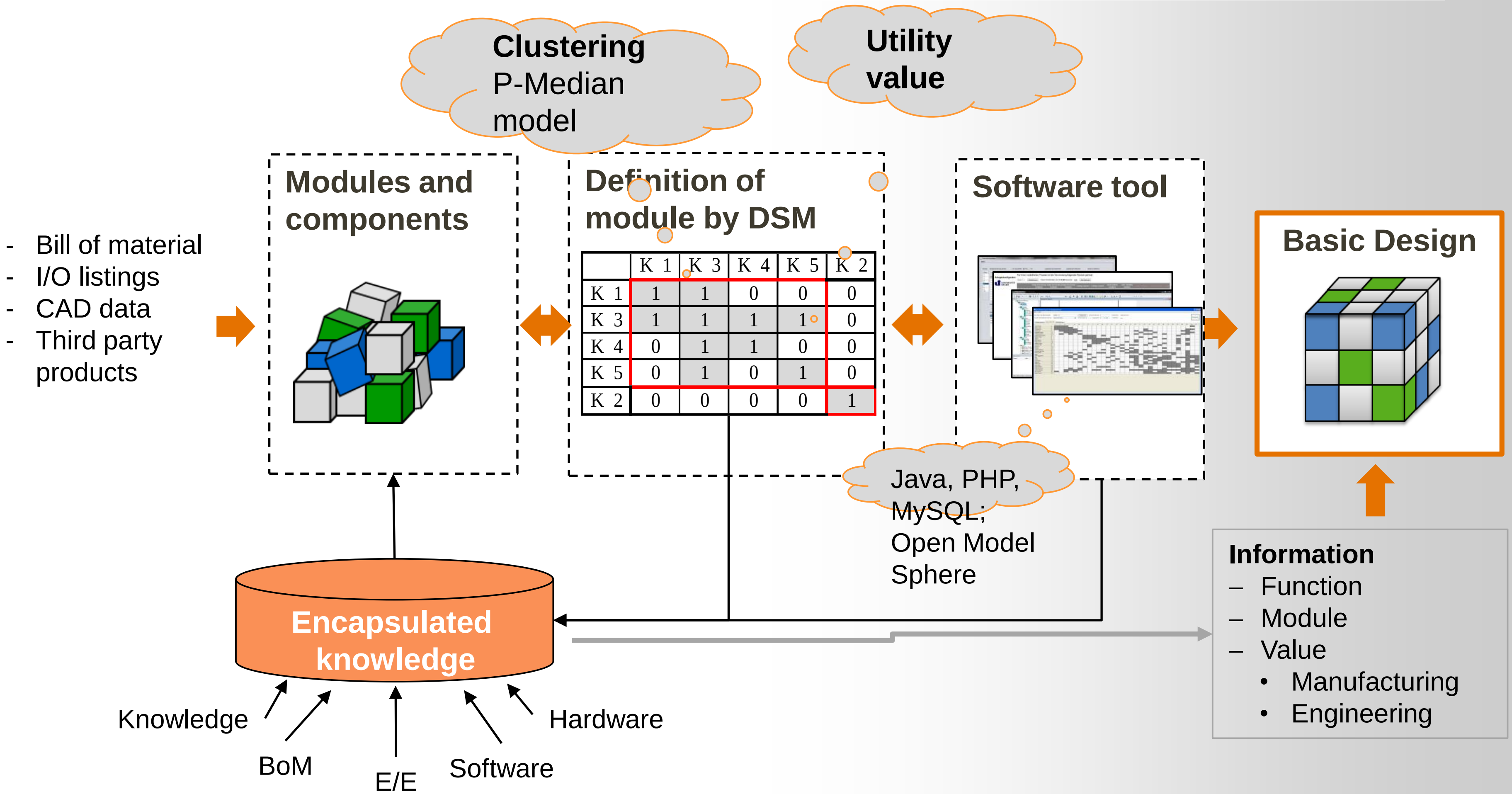
Is this component depended to the other component to fulfill a function?

Interaction	Weight
Required	2
Desired	1
Indifferent	0

Elements are grouped together as modules

Modularization for Engineering

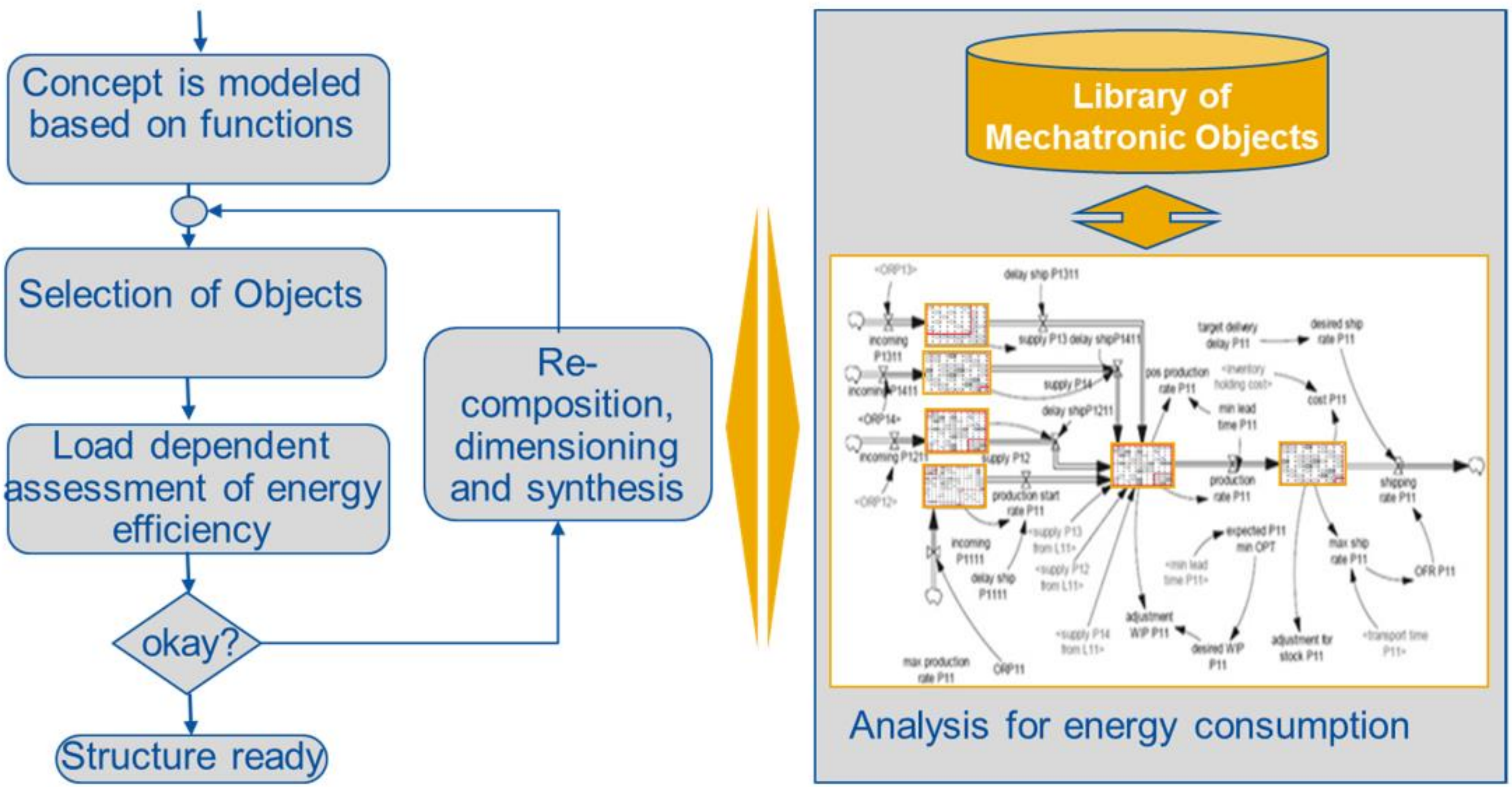
A Web-Tool is available for data processing, clustering and value analysis



	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

Evaluation and Optimization

Modelling and simulation is based on function and modules



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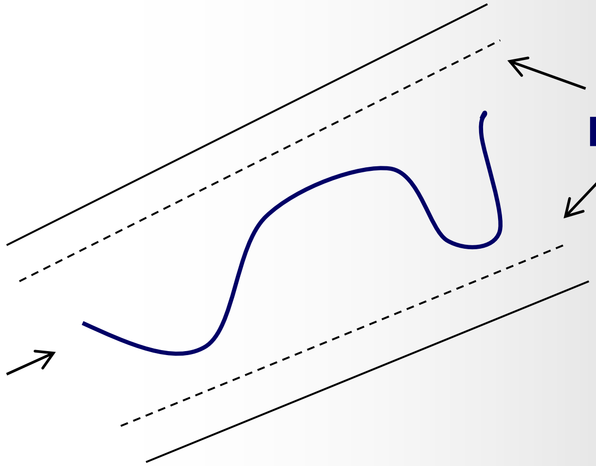
„Moving Design to Runtime“

Smart engineering through learning and self-configuration

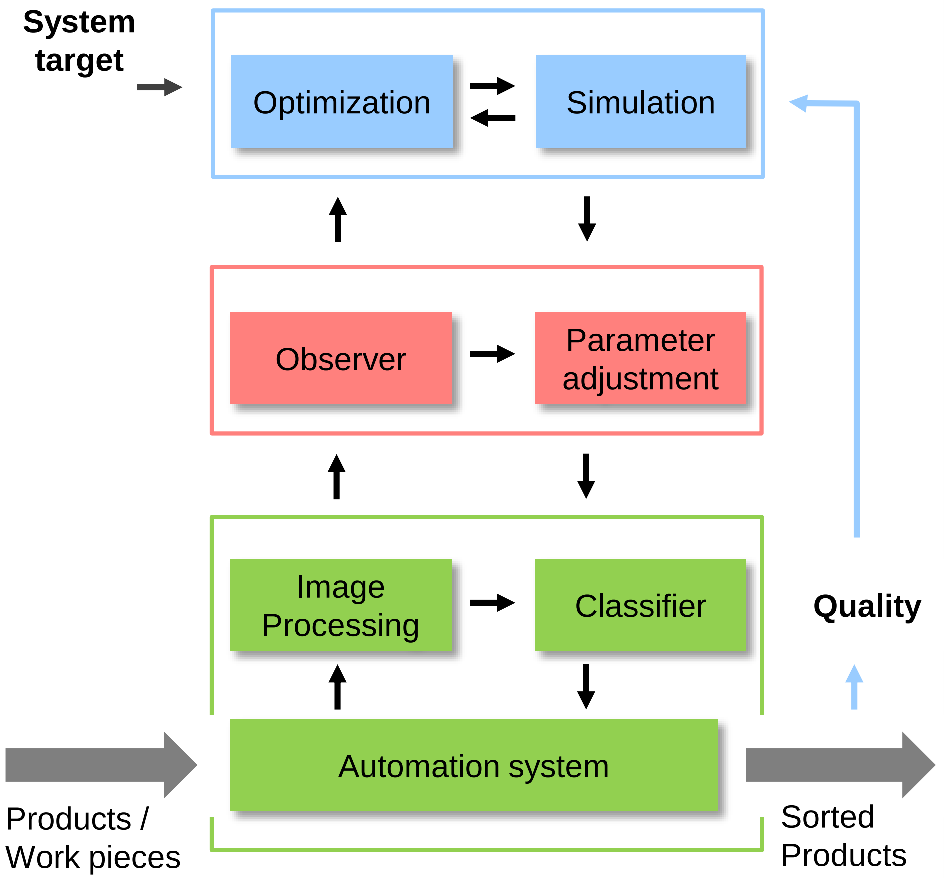
Method: Configuration of automation systems through an agent-based Configuration of preconceived Components.
=> Flexible and Re-configurable

Challenge of learning from the perspective of the engineer

- Keep system compliant with changing requirements



Learning Architecture
(Example of industrial image processing)



Layer 3

Optimization
- Simulation-based optimization of models (closed loop control)

Layer 2

Adaption layer
- Observation for parameter adjustment (open loop control)

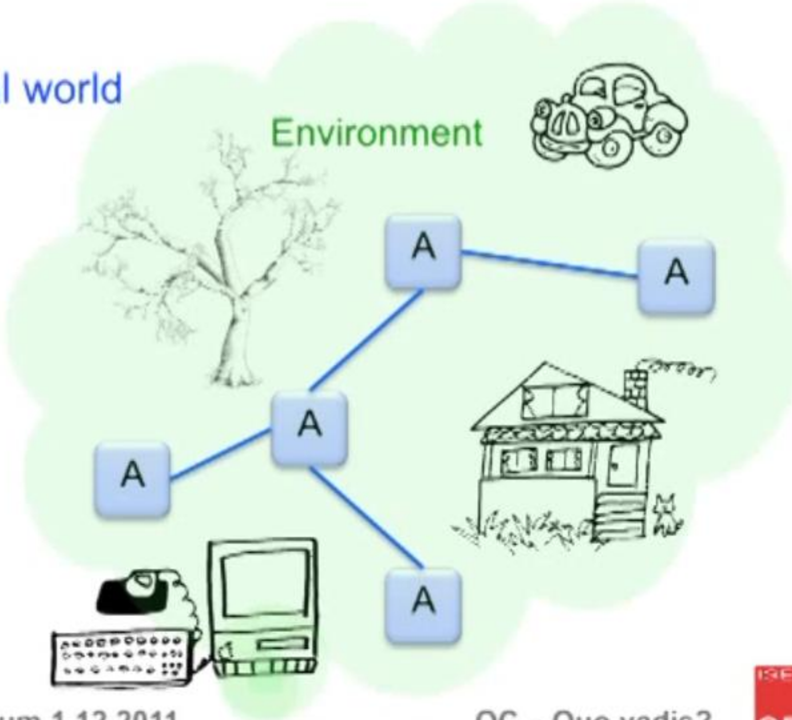
Layer 1

Execution layer
- Image processing with classifier
- Product recognition
- Camera-guided robot

Citation of the DFG SPP: Organics Computing

5 Lessons learnt

1. OC means: Move design time decisions to runtime!
2. „Self“ is nothing magic, it has to be done.
3. Principle of non-critical complexity
4. No decentralization at any cost!
5. OC is about agents situated in a real world
   - Cognitive agents
   - Social agents



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22 HNI-Forum 1.12.2011 OC – Quo vadis?

Quelle: Prof. Christian Müller-Schloer, Leibnitz Univ. Hannover, Vortrag „Organic-Computing – Quo vadis?“; http://www.youtube.com/watch?v=ebHgJc4sTKY

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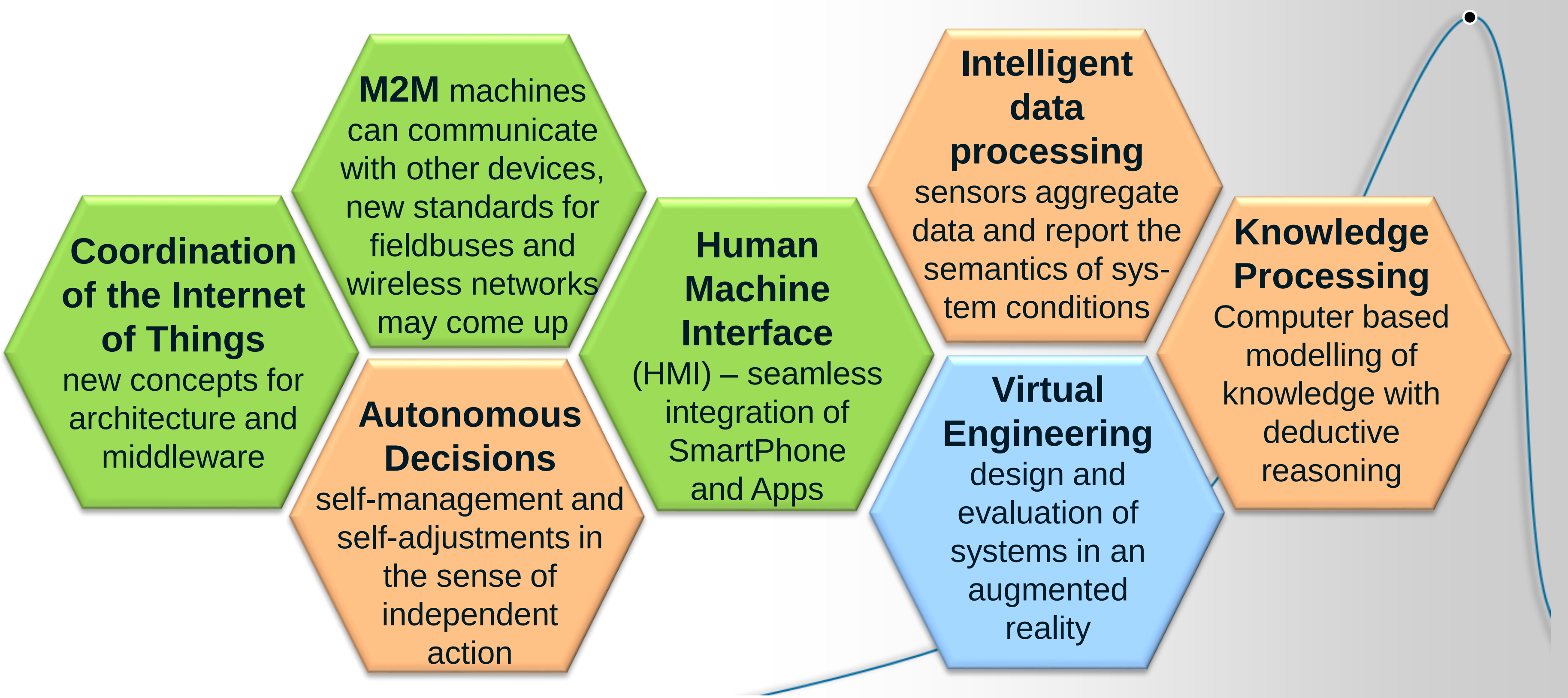
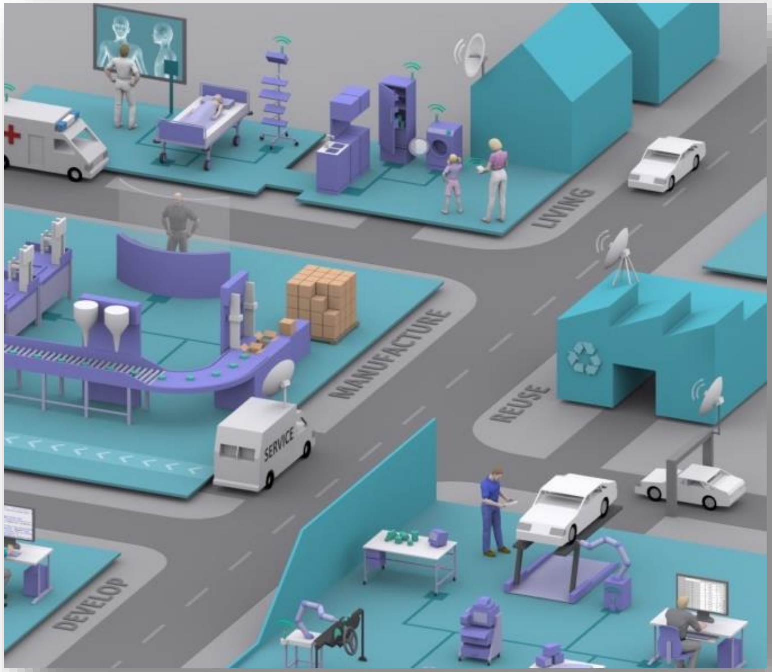
Seamless integration of Automation Technology

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.)