DEVELOPING INTELLIGENT SYSTEMS – METHODS, BEST PRACTICE AND CHALLENGES

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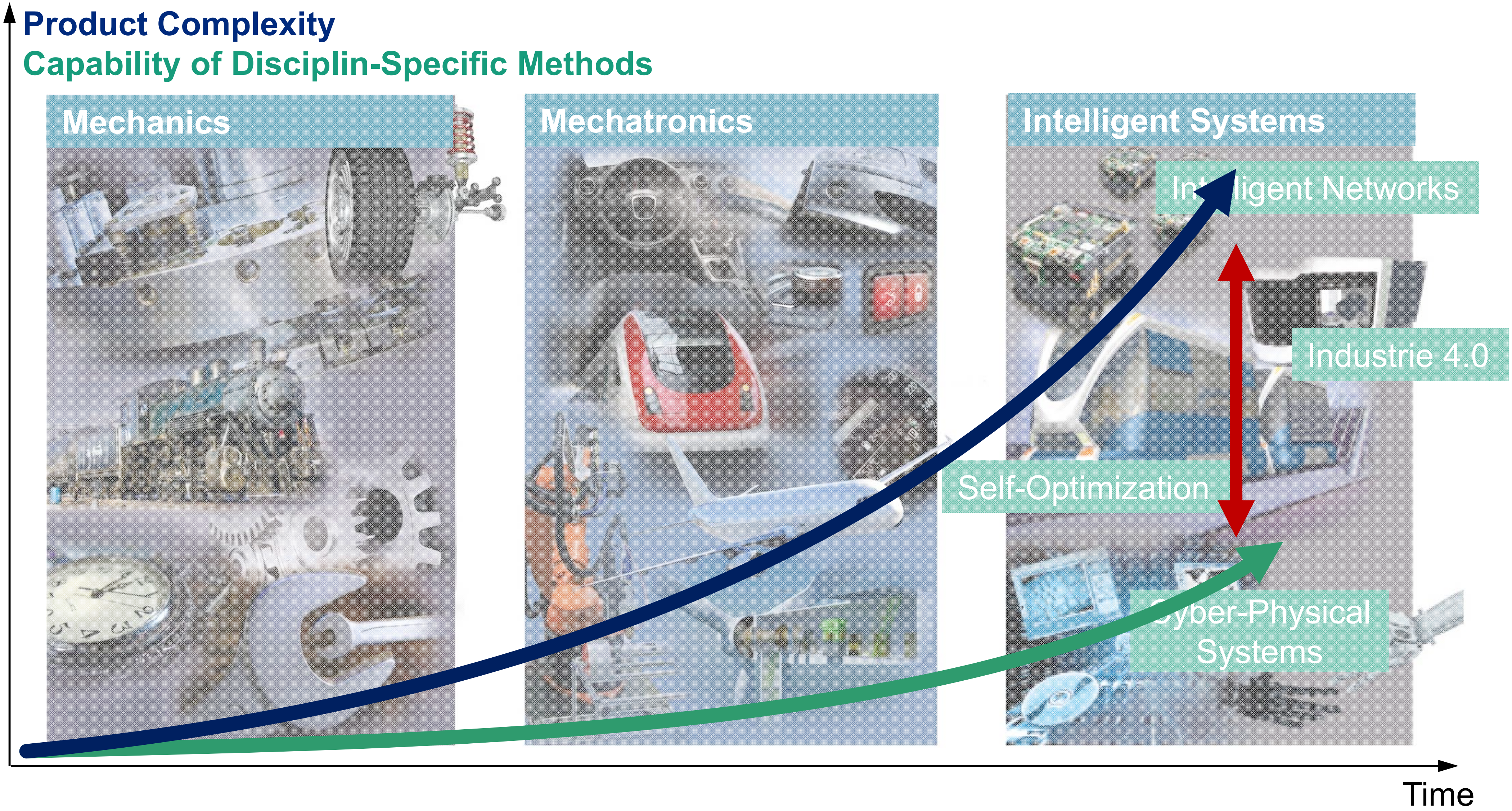
DEVELOPING INTELLIGENT SYSTEMS – METHODS, BEST PRACTICE AND CHALLENGES

Outline

1. **Introduction**
2. Technologies
3. Applications

Innovation Leap Towards Intelligent Technical Systems



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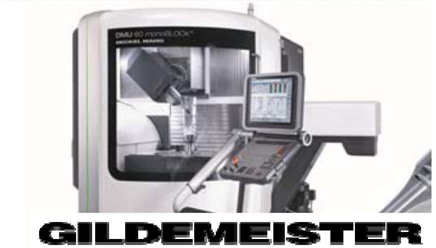
Intelligent Technical Systems…

… interact with the environment adapting to it autonomously (**adaptive**)

… manage even unexpected situations not taken into account by the developer in a dynamic environment (**robust**)



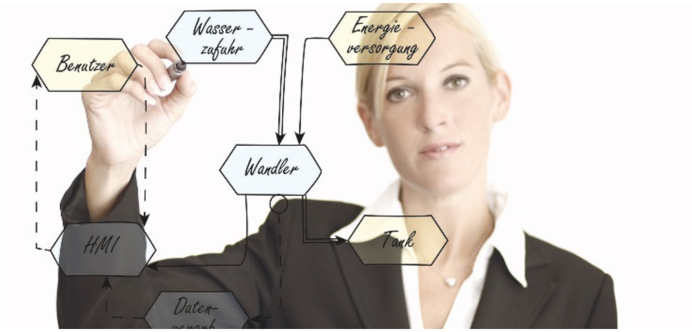
… anticipate on the basis of experiential knowledge future effects of influences and possible states (**anticipatory**)

… take into account individual user behavior (**user-friendly**)

Our Competencies for Developing Intelligent Systems

Intelligent in Technical Systems:

- Concepts for advanced control, implementation of Self-X-capabilities like self-diagnostics, -configuration, -healing



Systems Engineering:

- Discipline-spanning engineering methods, system specification, modularization and integration, simulation and verification

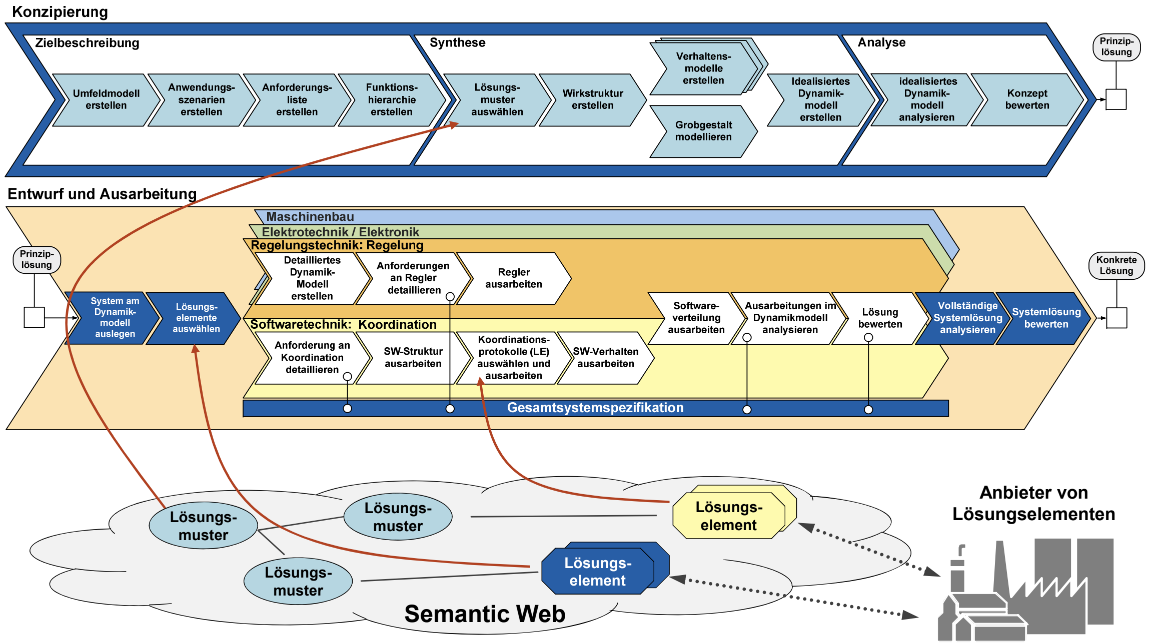
Virtual Engineering:

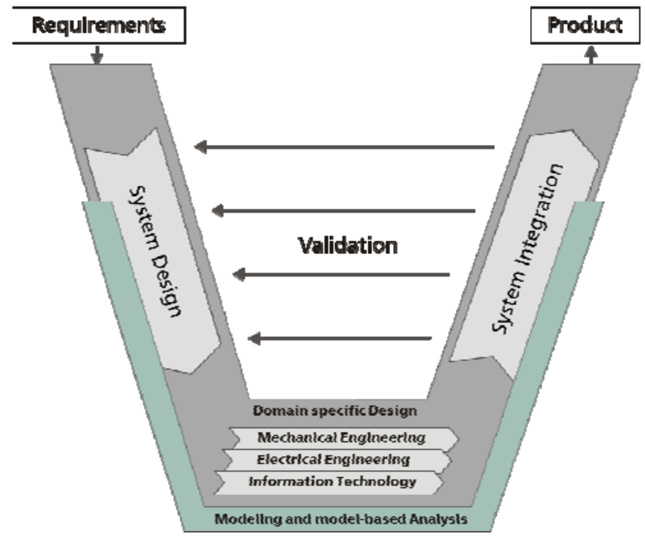
- Reduction of time consuming and cost intensive real prototypes by techniques using digital mechatronic models

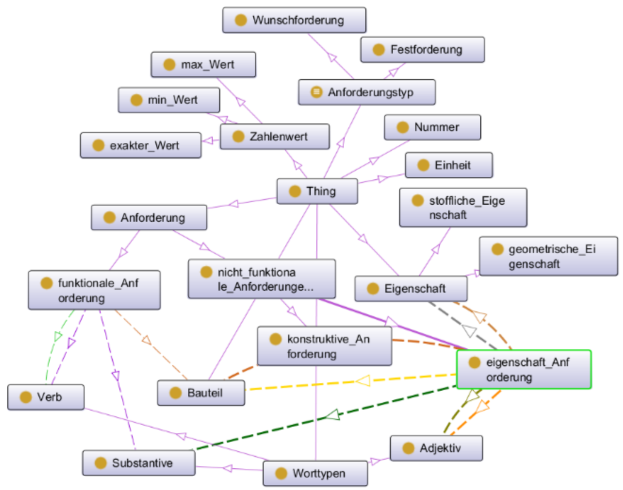
DEVELOPING INTELLIGENT SYSTEMS – METHODS, BEST PRACTICE AND CHALLENGES

Outline

Design Methodology for Intelligent Systems







- Reference process for system design using semantic techologies
- Ontology based representation of solution patterns / solution elements

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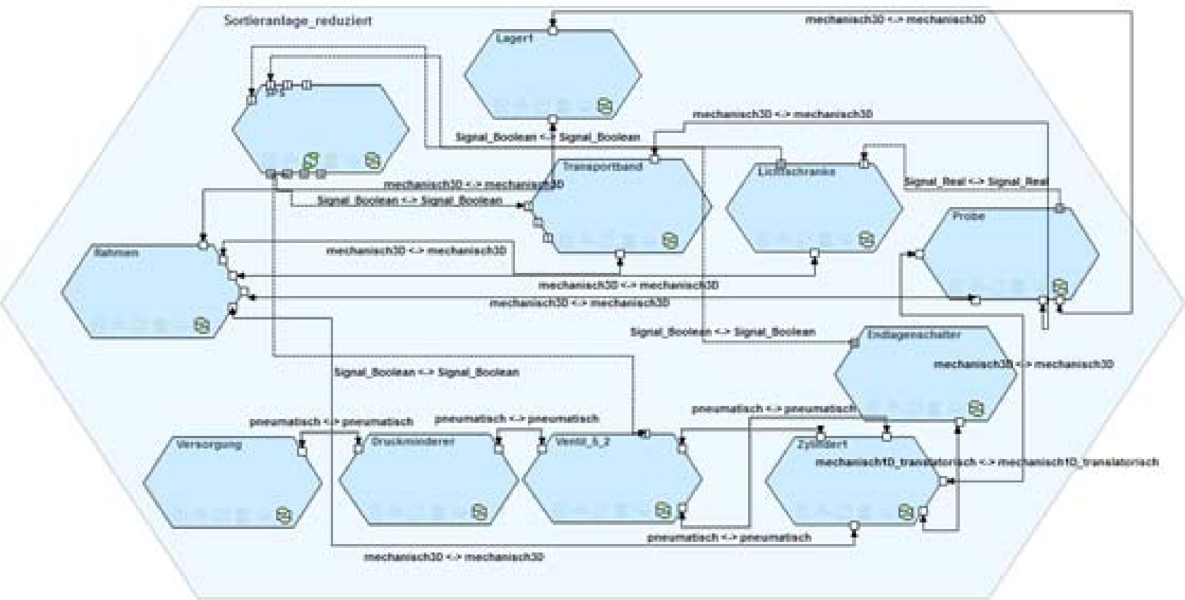
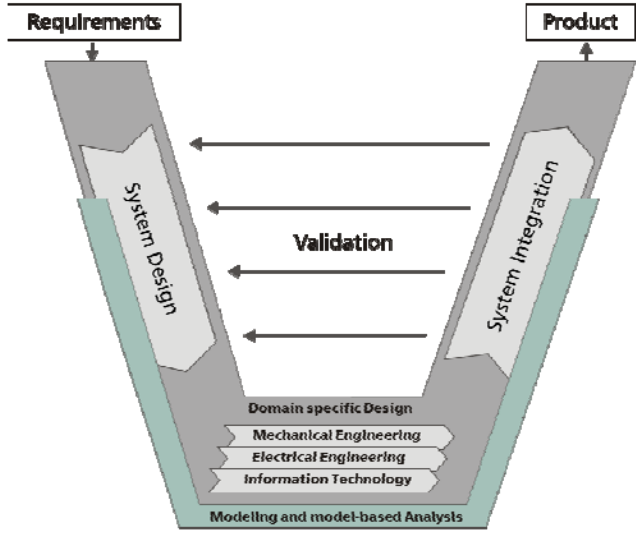
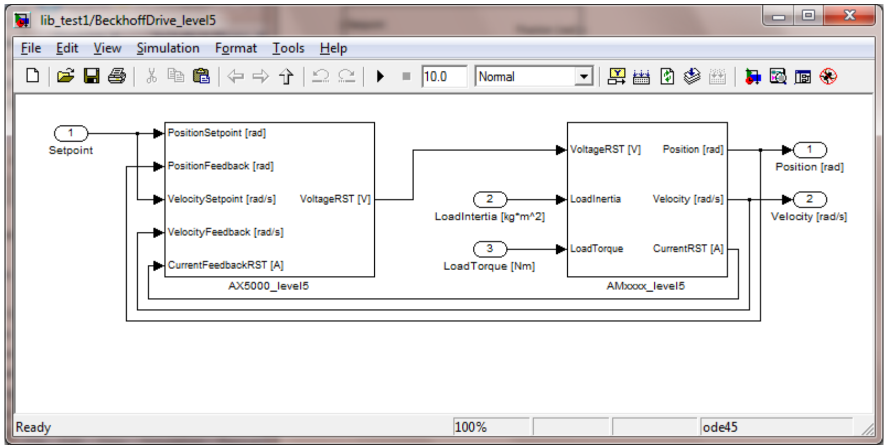
Design Methodology for Intelligent Systems





- CONSENS: language for domain spanning system models
- Automatic generation of behavioral models



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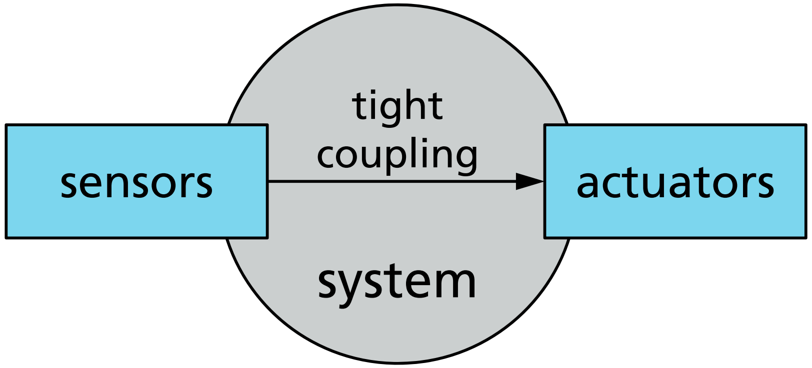
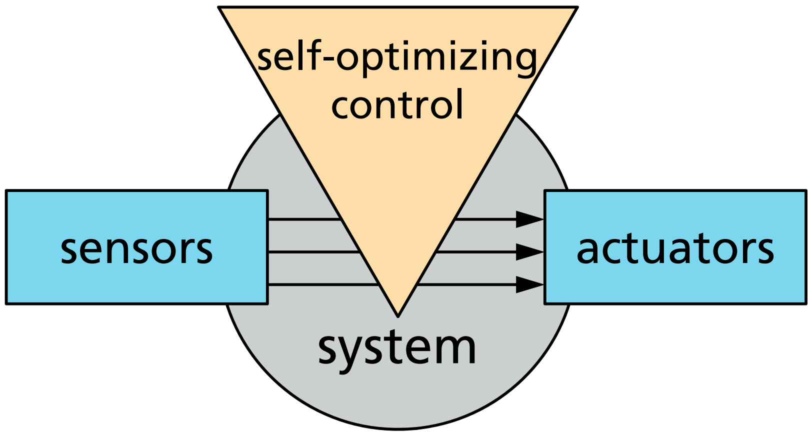
Self-Optimizing Control Systems

reactive system



intelligent system



Classical control system:

- Tight coupling between sensors and actuators
- Limited adaptibility

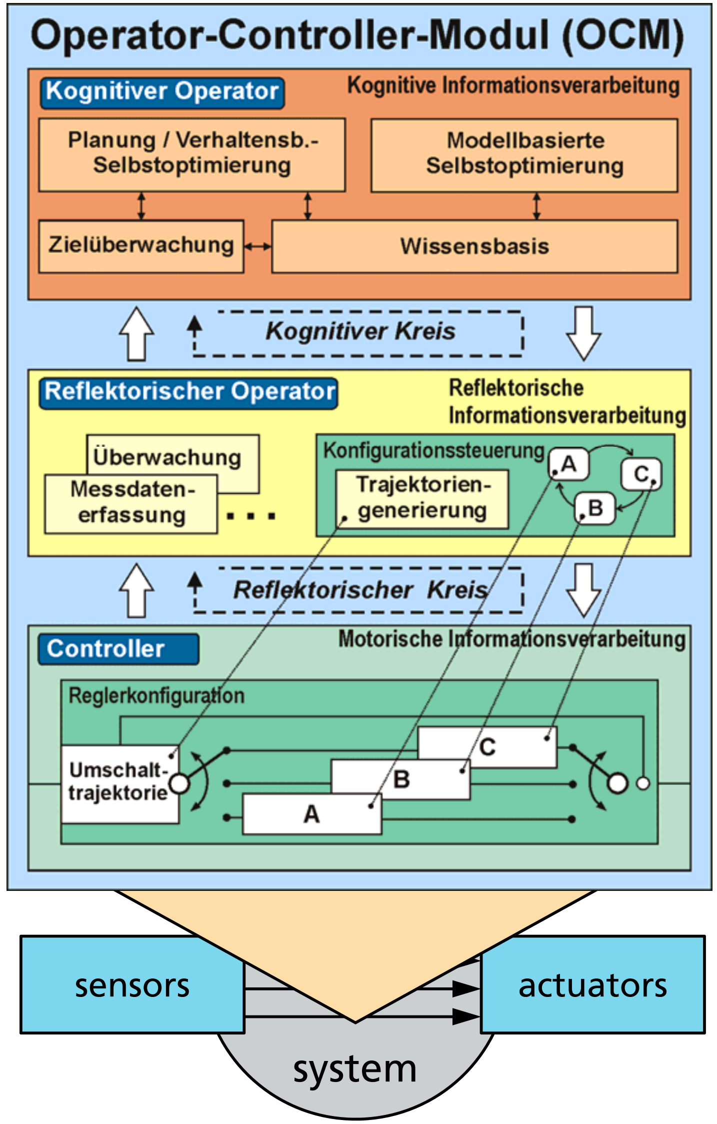
Self-optimizing control system:

- Adaptation to changing goals in volatile environment
- Robust, anticipatory system behavior

Self-Optimizing Control Systems

3-level control architecture

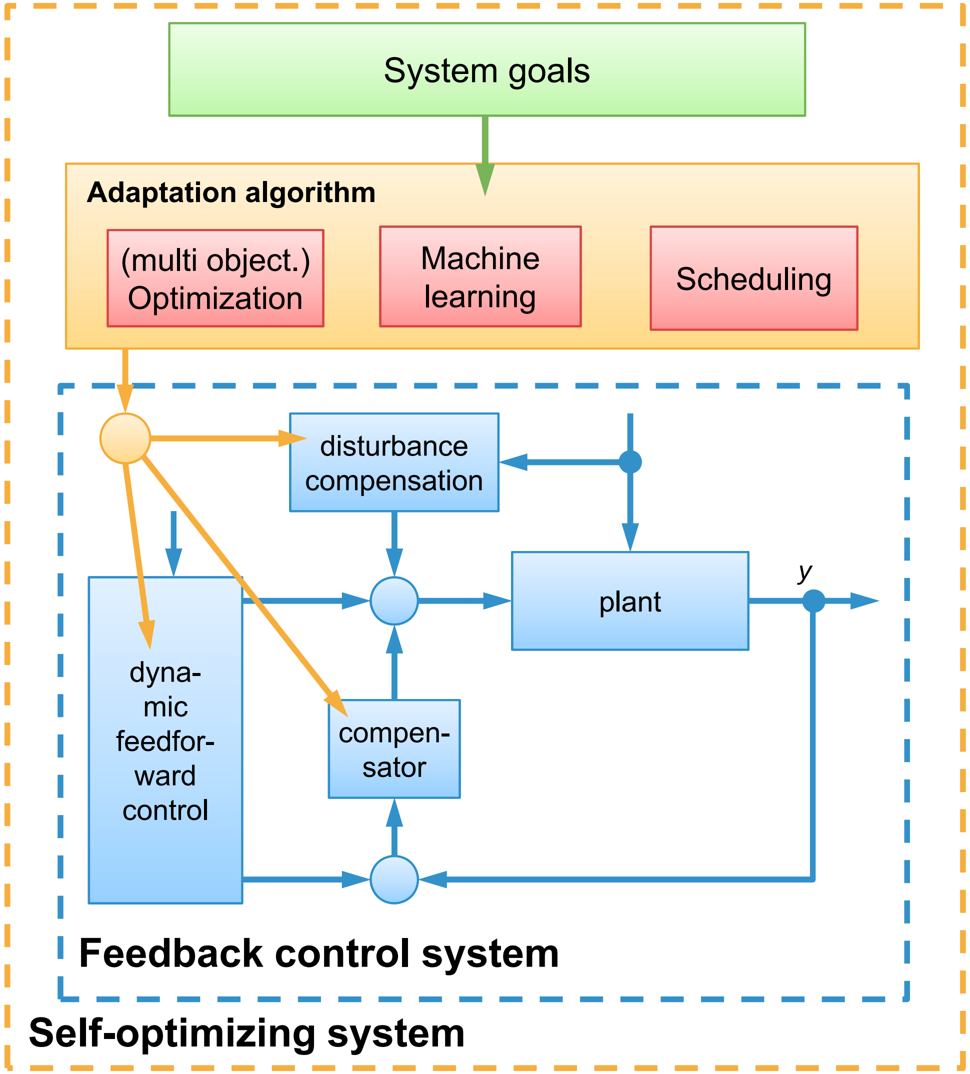
- **Controller:** classical control, hard real-time
- **Reflectoric Operator:** event-triggered monitoring and adaption of the controller
- **Cognitive Operator:** soft real-time, computationally intensive algorithms
  - (model based) optimization
  - machine learning / scheduling
  - supervision and control of several objectives



Self-Optimizing Control Systems

Highly adaptive, intelligent system behavior:

- Optimal control
  - Dynamic feedforward control
  - Switching between several control laws
- Control based on Pareto sets
  - Situation dependent choice of optimal compromises
- Model-predictive control
- Non-linear State observers
  - Virtual sensors / condition monitoring
  - State feedback control



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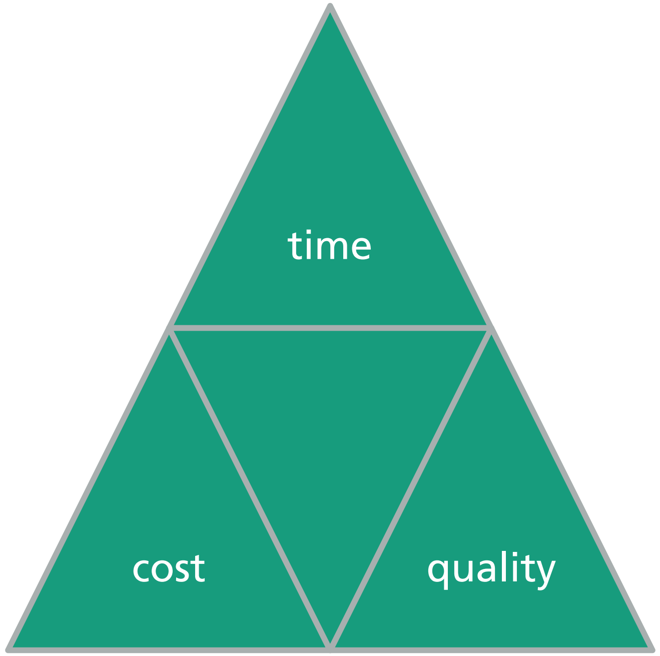
Self-Optimizing Control Systems
Multi-objective Control



Challenge

- Concurrent objectives (cost / quality, safety/ efficiency etc.)
- volatile environment

Model-based numeric optimization

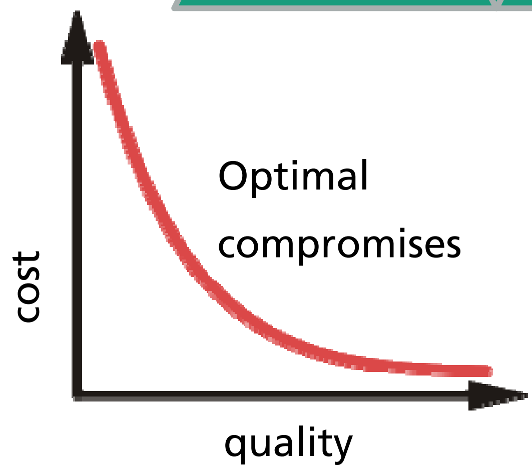
- Calculation of objectives
- Control design

Multi-objective Optimization

- Simultaneous consideration of multiple objectives

Hierarchical Optimization

- separate optimization on subsystem-level

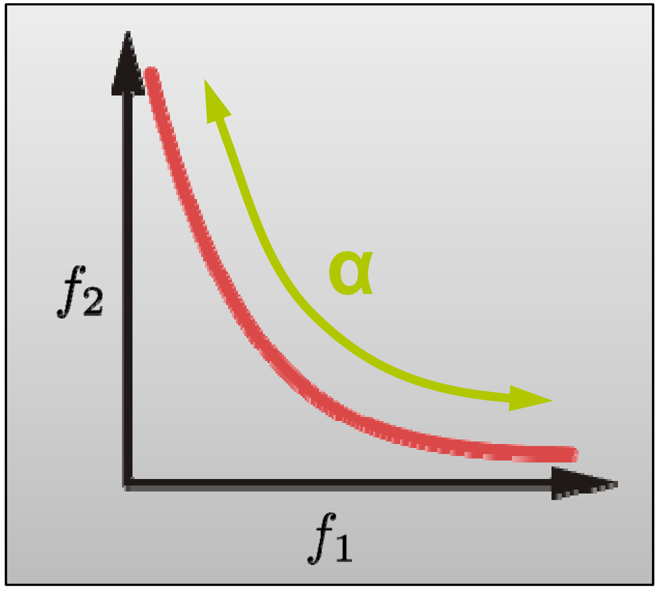


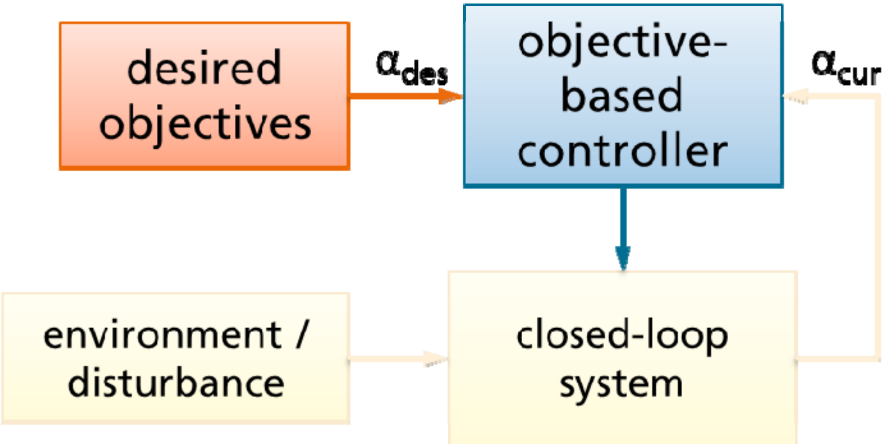
Self-Optimizing Control Systems
Objective-Oriented Control

- conflicting objectives
- Pareto set of optimal compromises
- parametrization by weighting factor α

Goal:

- Drive the system toward a desired weighting of objectives (desired α)
- Despite unpredictably changing disturbances





objective-oriented control

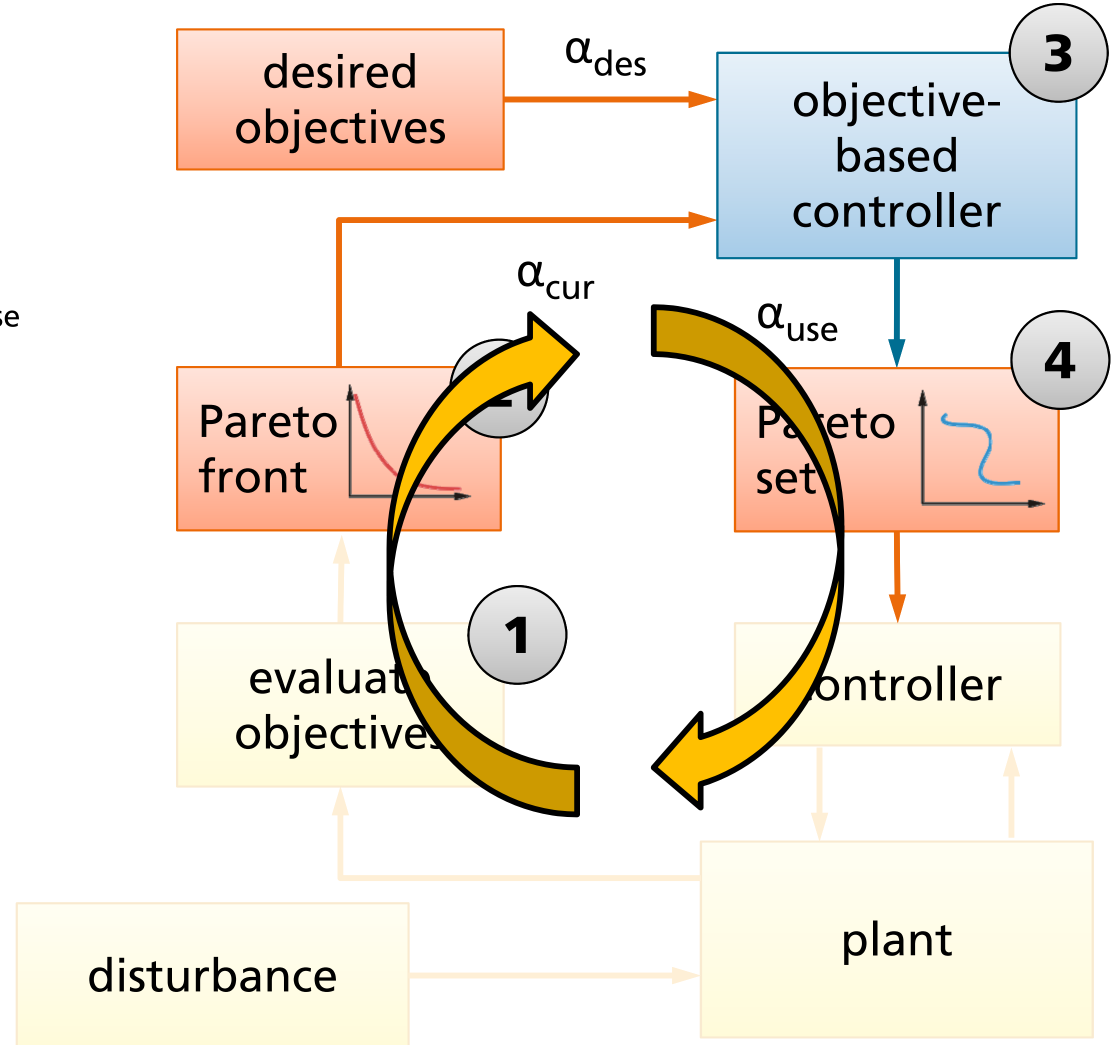
- Operates a level "above" the close-loop system
- Considers the current and desired α values
- Updates control parameters to drive system toward α_{des}

Self-Optimizing Control Systems

Objective-Oriented Control

1. evaluate objectives based on measurements
2. read off α_{cur} using Pareto front
3. compare α_{cur} with α_{des} and compute α_{use}
4. read off controller configuration for continuous controller using Pareto set

(Outer control loop: update of objectives)



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DEVELOPING INTELLIGENT SYSTEMS – METHODS, BEST PRACTICE AND CHALLENGES

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1. Introduction
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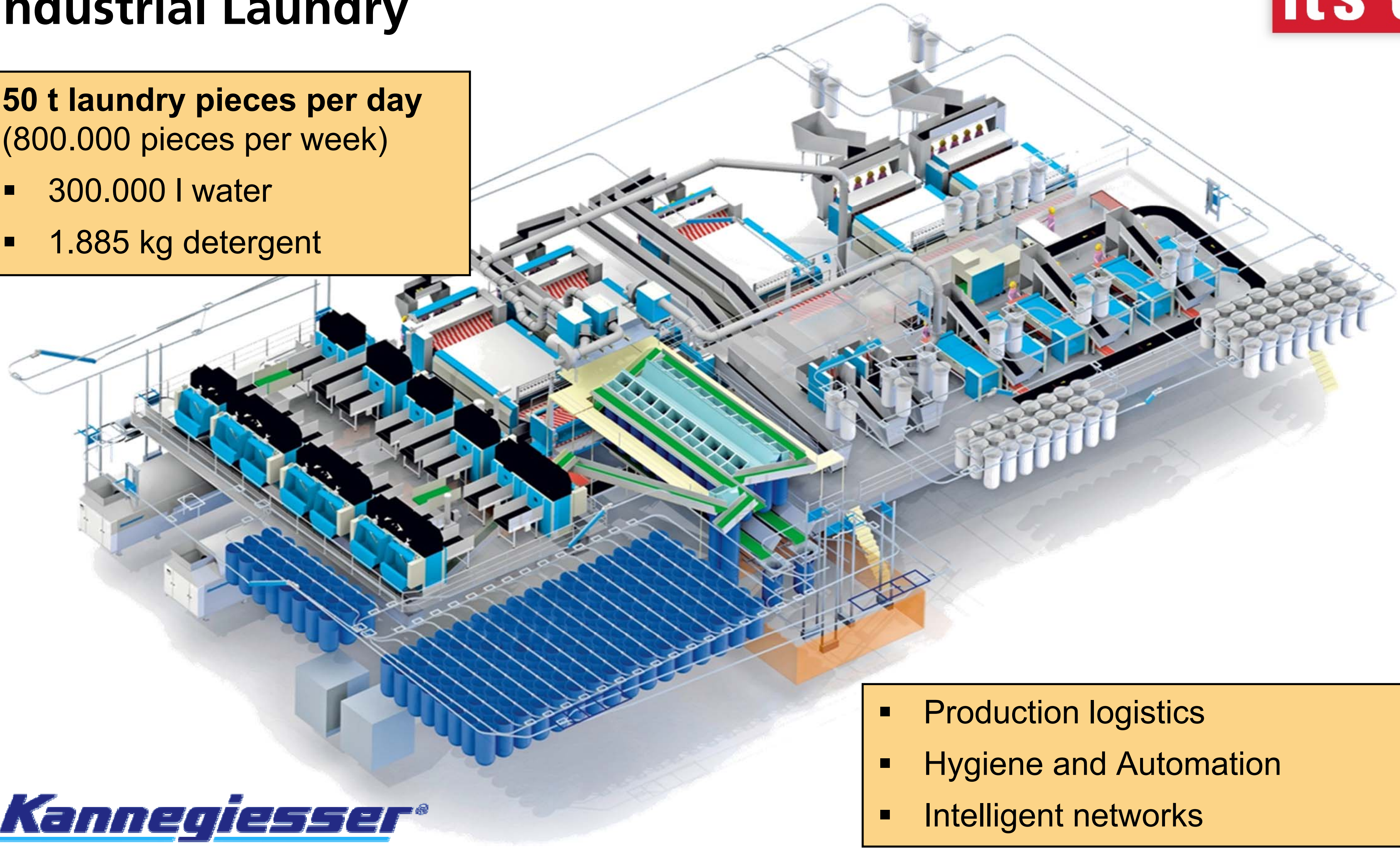
3. **Applications**
    1. Self-Optimizing Resource-Efficient Industrial Laundry
    2. Intelligent production machines

Self-Optimizing Resource-Efficient Industrial Laundry

50 t laundry pieces per day
(800.000 pieces per week)

- 300.000 l water
- 1.885 kg detergent



- Production logistics
- Hygiene and Automation
- Intelligent networks

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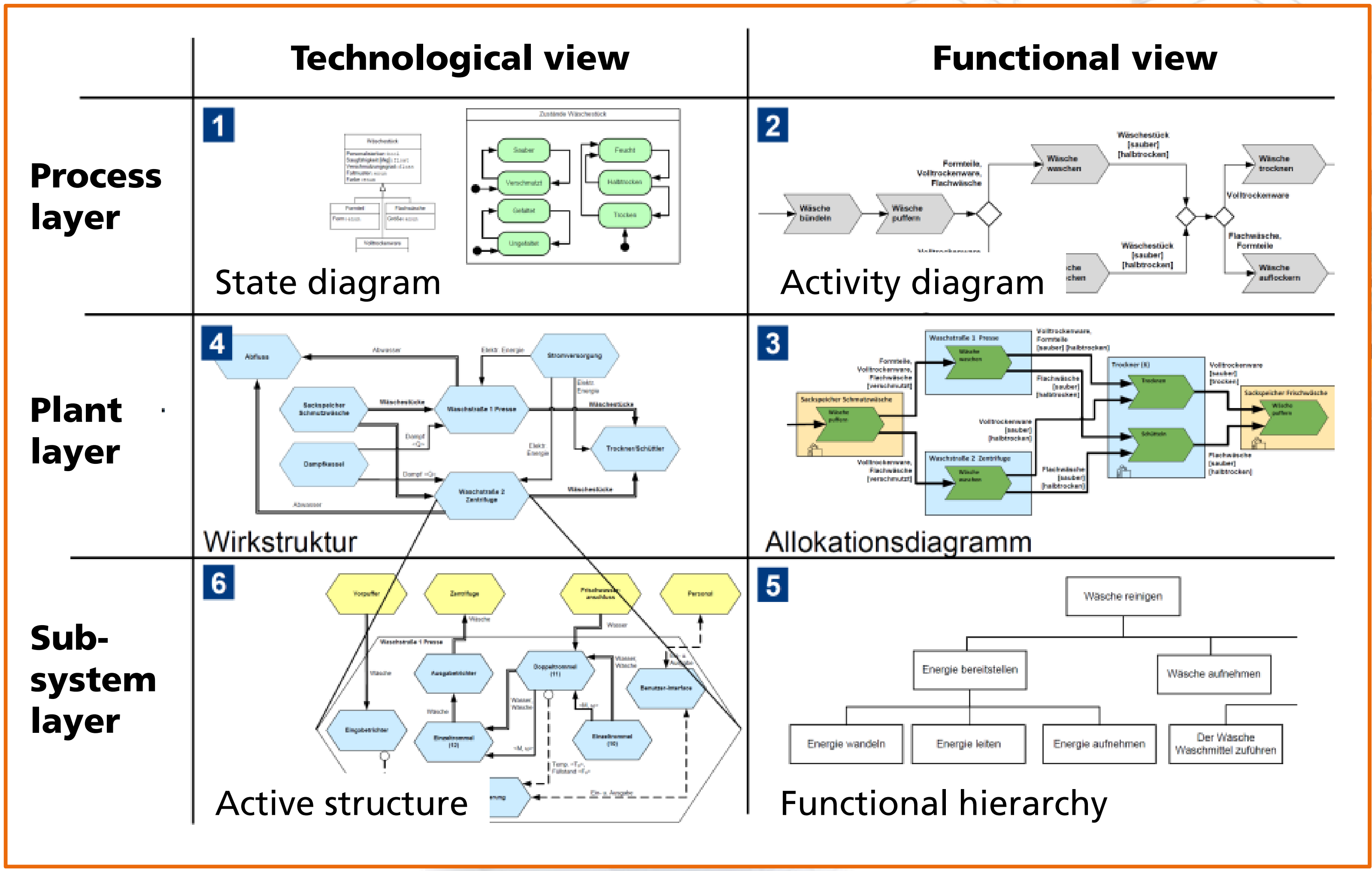
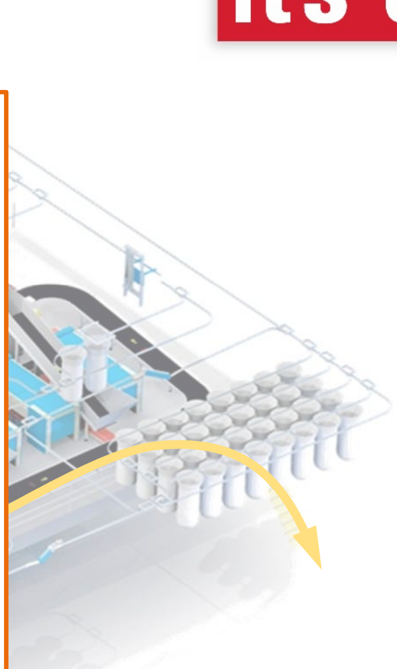
Production logistics





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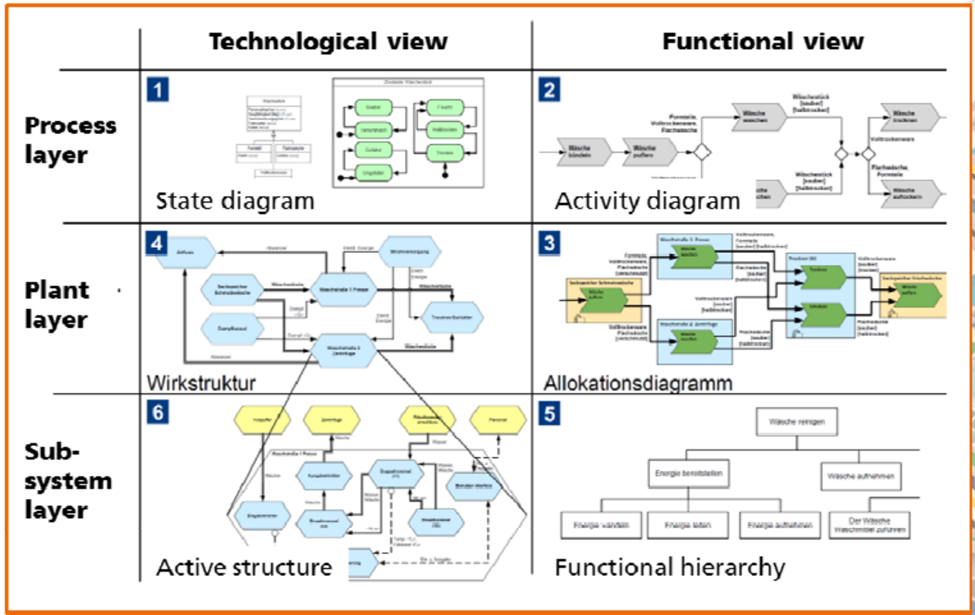
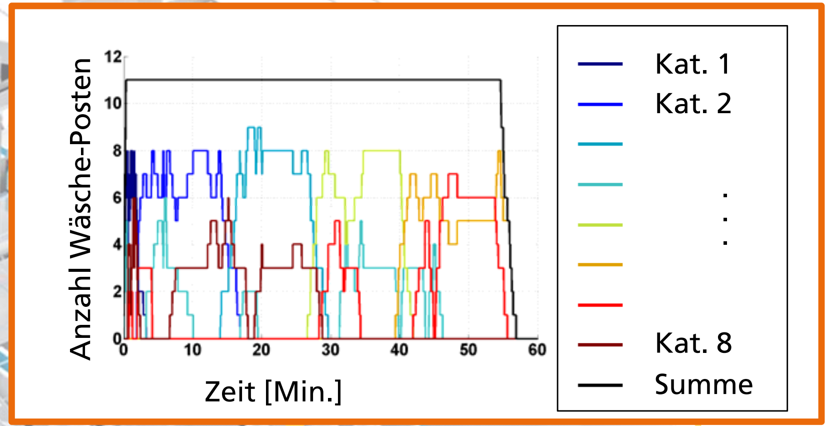
Production logistics





Simulation based optimal operation planning for the entire laundry

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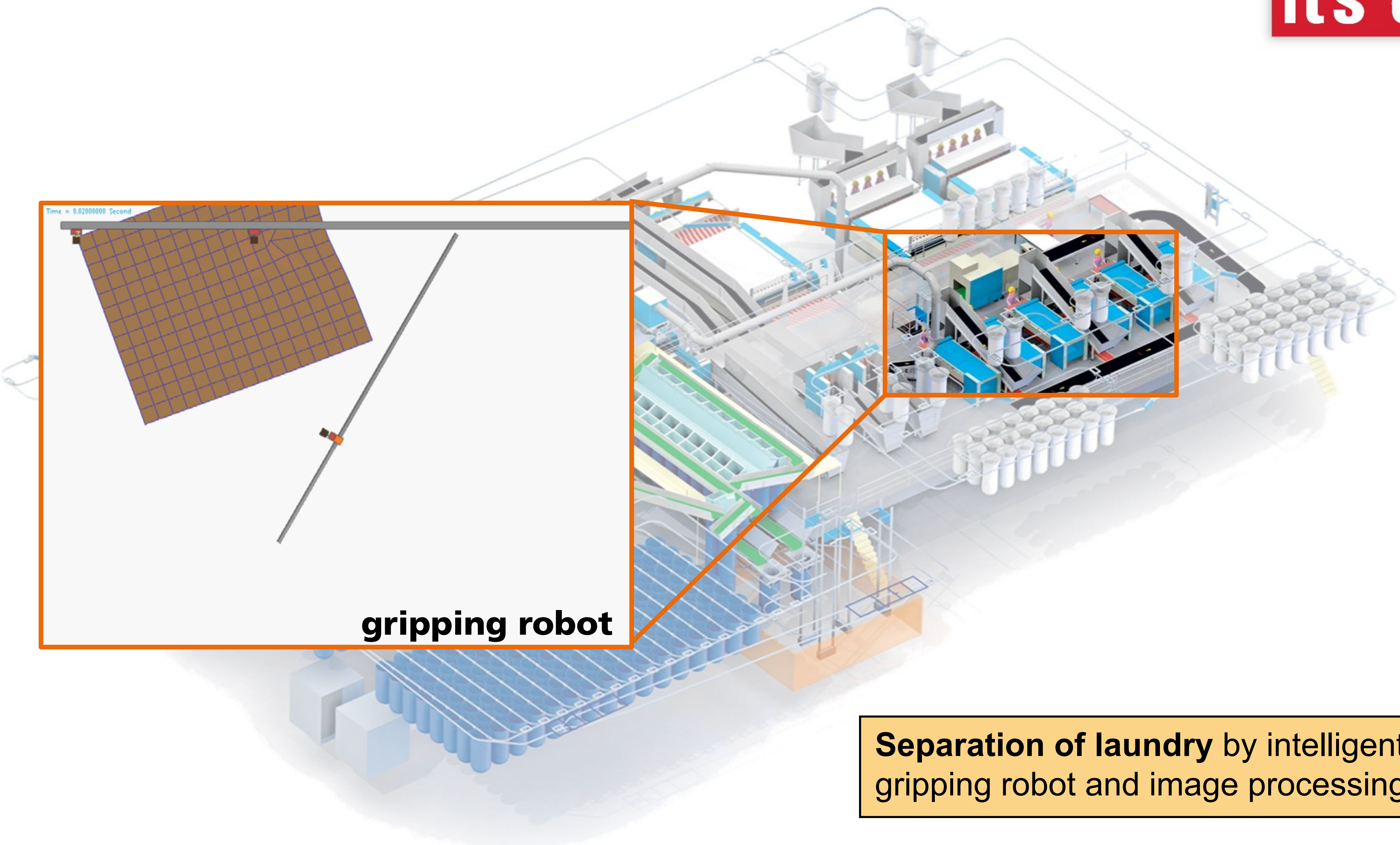
Das Technologie-Netzwerk:
Intelligente Technische Systeme
OstWestfalenLippe
it's owl

Hygiene and Automation



Separation of laundry by intelligent gripping robot and image processing.

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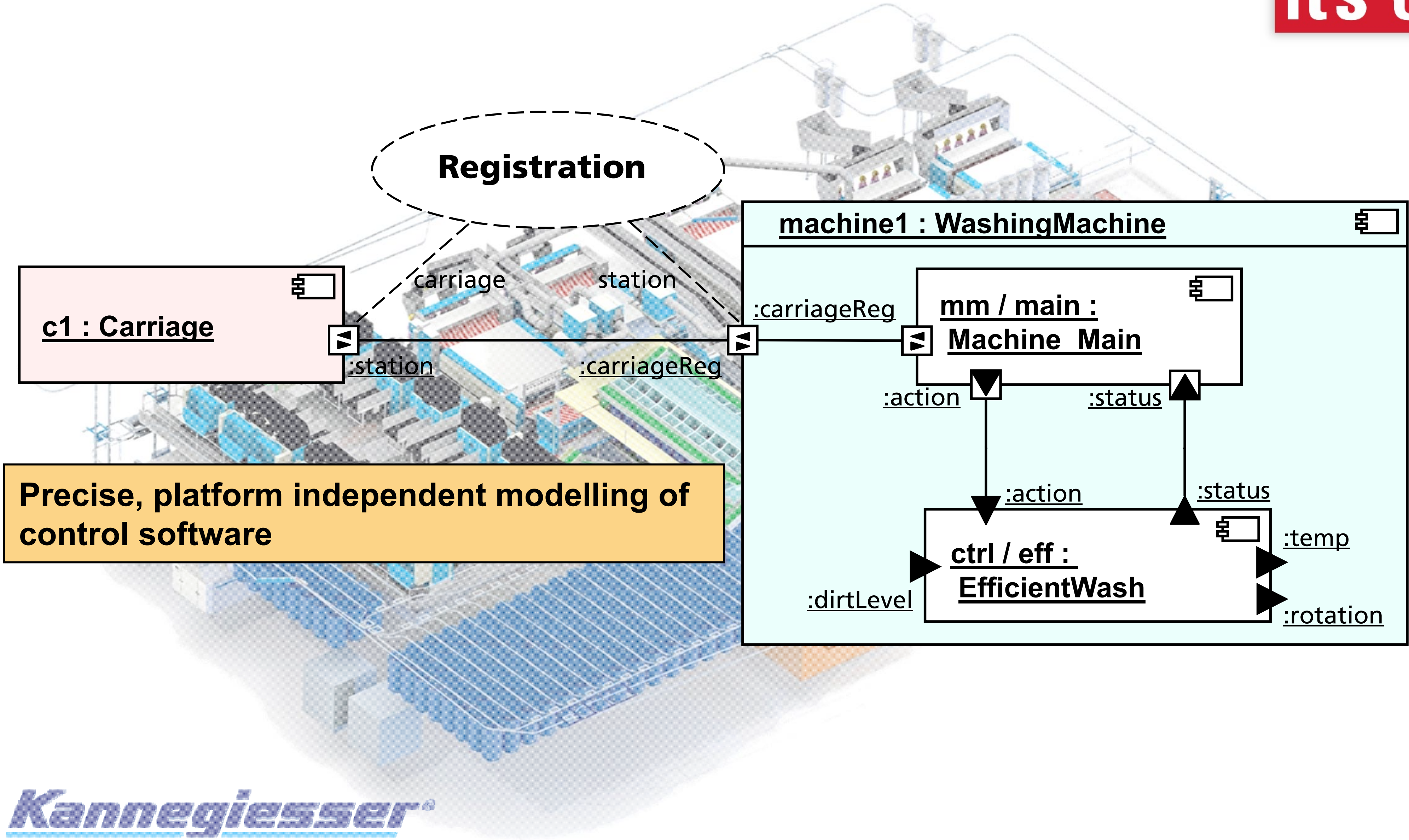
Intelligent networks



Precise, platform independent modelling of control software

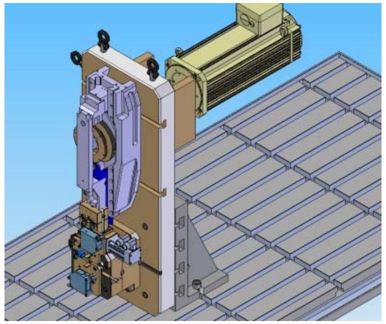
Intelligent production machines

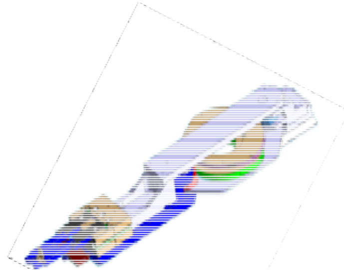
Challenge:

- Changing materials properties
- Varying environmental conditions
- Deterioraiton of product quality

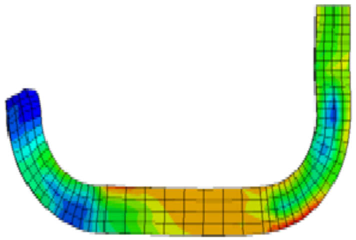
Solution:

- Analysis of dynamical processes
- Identification of materials properties
- Adaptive in-line process control

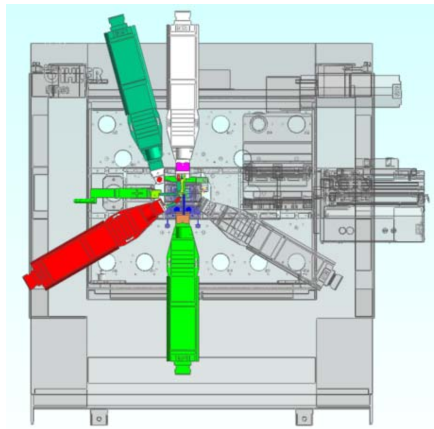




Analysis of machine dynamics



materials analysis



Self correcting production process

Intelligent production machines

Self-correcting punching and bending tool

Zusammenarbeit mit
Weidmüller
BIHLER

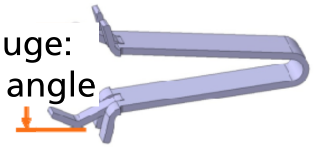
Quelle: Bihler

punching and bending tool

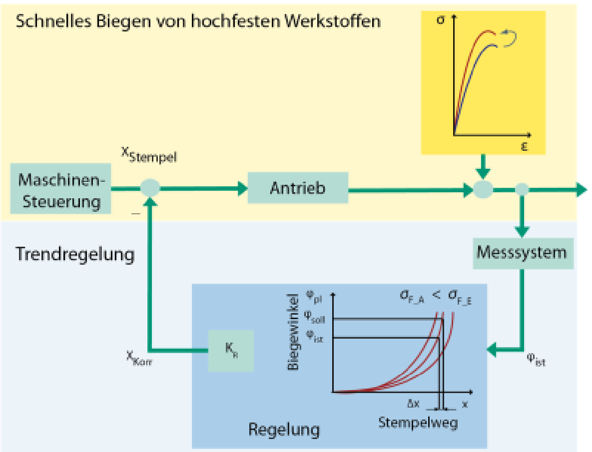
Quelle: Bihler

Component: spring clip

Check gauge:
Opening angle



Quelle: Weidmüller



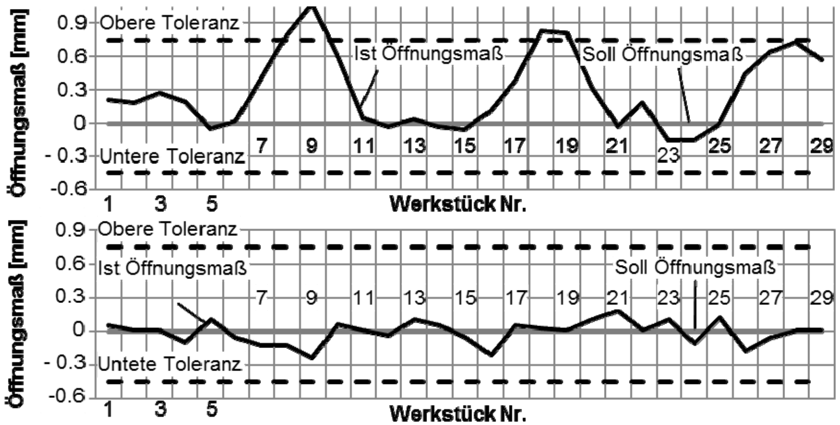
Design of the self-correcting strategye

Trends

- Miniaturization of components
- Reduction of admissible tolerances
- High-strength materials

Solution

- Self-correcting punching and bending tool with continuous in-line correction



results

0 % rejects

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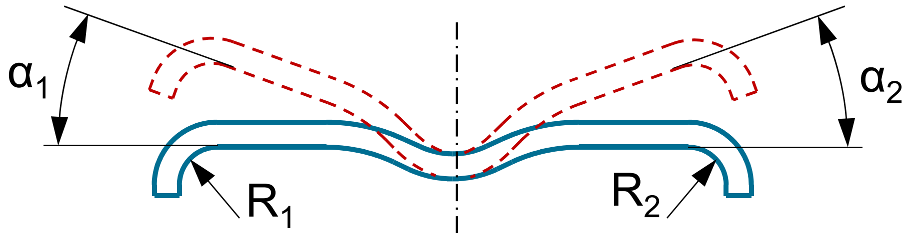
Intelligent production machines
Continuous forming process

Zusammenarbeit mit



- **Motivation**:
  varying raw stock properties, wear of tools, etc. deteriorate product quality
- **Goal**: Implementation of self-correcting technologies for autonomous control of profile characteristics ($R_{1,2}$ and $\alpha_{1,2}$)
- **Realisation:**
  - Model-based design of process control
  - Integration of industrial-suited sensors, actuators, and automation hardware

Quelle: Hettich

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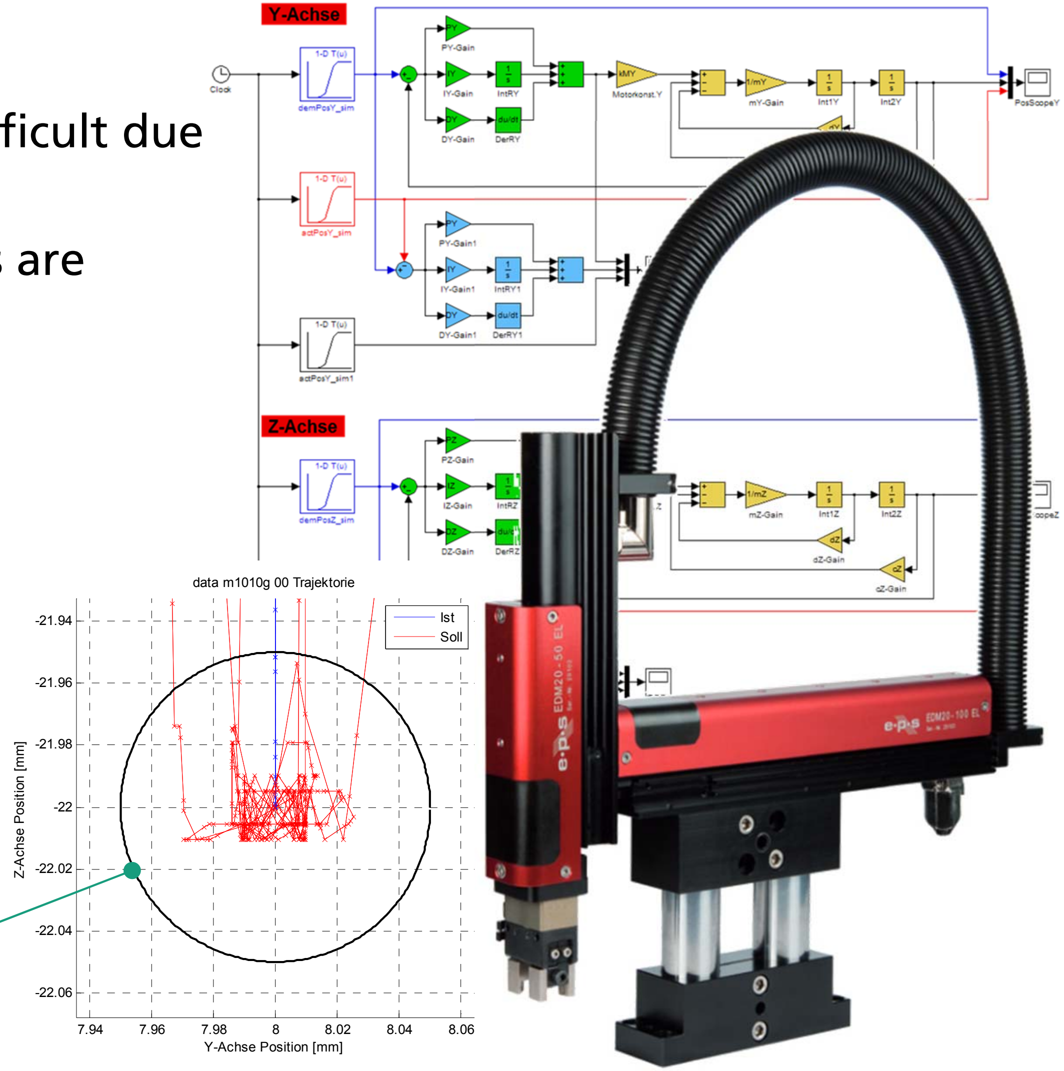
Intelligent production machines

Semi-adaptive control of a pick&place-module

Zusammenarbeit mit PHOENIX CONTACT

- **Motivation:**
  - Precise control parameter adjustment difficult due to lacking environmental model
  - Requirements for precision and dynamics are violated
- **System analysis**
  - Realization of data logger via CANopen
  - Effect analysis of relevant features
- **System optimization**
  - Modelling and identification
  - Model-based Controller design
  - Implementation and validation



Tolerance interval of 50 µm is met with full prodution rate

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THANK YOU FOR YOUR KIND ATTENTION

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