Trends that Shape the Future of Automation Engineering
On Cyber-physical Systems, Smart Components and other Innovations

Institute of Industrial Automation Technology and Software Engineering (IAS)
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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

University Professor
- Chair of Manufacturing Automation, University of Siegen
- Institute of industrial Automation Technology and Software Engineering, University of Stuttgart
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- State-of-the-Art and Vision
- Cyber-physical Systems
- Technologies for the application domains
  - Automotive and Consumer products
  - Manufacturing Industries
- Aspects of research, open questions and conclusion
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Which Technologies are promising changes towards Disruptive Innovation?

The „Gardner Hype Cycle“ methodology provides a view on how technologies could evolve over time (here: personal assessment of buzz words).

- **Technological Trigger**
- **Peak of inflated Expectations**
- **Disillusionment**
- **Plateau of Productivity**

Key Technologies:
- CPS
- Big Data
- “Industrie 4.0”
- Organic Computing
- AI

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Prime Example for Disruptive Innovation

Success story of the Apple-iPhone: on how Apple revolutionized the business model based on technology

**Business Model:**
creation of an ecosystem for Apps and downloads such as music, games and navigation

**Technology:**
new chips, data centers and software (e.g. Apps)

**Redefinition of the utility value of a phone**
– meets requirements which were unavailable to users before

**Useful and elaborated sophisticated functionality**
activates the genius of developers

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Vision: Smart Units / Nodes in the Internet of things and services are automating the world

Source of Picture: Wikimedia Commons

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A cyber-physical system (CPS) is a system of collaborating computational elements controlling physical entities.

Weiser: “Next comes ubiquitous computing … when technology recedes into the background of our lives”; “… it won't be done until everything is on the Web …”
Cyber-physical Systems

Smart, networked Systems as a game-changer: New ways of cooperation among distributed and intelligent units as well as with human

Communication Infrastructure

Actuators

Object / Unit

Sensors

Control

Cooperative Systems

Information processing

Human-machine interface

Human

Environment
Cyber-physical Systems

Smart, networked Systems as a game-changer: New ways of cooperation among distributed and intelligent units as well as with human

Evaluation and test of Smart Units

Learning and adapting during runtime simplifies the configuration

Communication Infrastructure

Cooperative Systems

Information processing

Control

Actuators

Object / Unit

Sensors

Systems

Environment

Human

Architectures and methods for quick and easy integration

Improved human-machine communication for interaction
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Research in Automation Technology revolves around the application domains

- Urban Life
- Manufacturing Industries
- Automotive

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Networking Technology of the Car changes the process of Development

- The number of ECU (Electronic control units) 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)

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Urban Life is being automated
Award-winning research for automated consumer products

RFID automates a drug cabinet
Coffee from the internet
Multi-modal HMI of a ticket vending machine
App based diagnosis of household appliances

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“The New Digital Age – Transforming Nations, Businesses and our Lives”*
Vision of Google: omnipresence of Cyberspace and physical world in the sense of a hybrid reality.

Google Project Glasses

Location-dependent information

Navigation

Paradigm change: Merging information from the internet, mobile communication and the physical world

Human machine interface

* see book of same name: Eric Schmidt (Google Executive Officer) and Jarred Cohen (Head Think tank Google Ideas);
Emerging information-technology platform that fundamentally changes the ways we interact with and live in information-rich world.

**Swarm operating system**
New operating system as mediating layer between apps, resources and the cloud?

[J. Rabaey, ASPDAC'08]
(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
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“Industrie 4.0”
Integration, Internet of things and services as well as Standards in the field of Big Data, Security and the business areas)¹

¹ Result of a meeting at the VDI Düsseldorf on 10. Juli 13: Participants: Prof. ten Hompel, Fraunhofer IML; Klaus Bauer, Trumpf; Dr. Dagmar Dirzus, VDI Wissensforum; Dr. Ralf Ackermann in SAP Research Center; Prof. Dr. Dieter Wegener, Siemens AG, Dieter Westerkamp, VDI; Prof. Dr. Michael Weyrich, Universität Stuttgart; Christoph Winterhalter, ABB AG; Dr. Heyjo Jacobi, VDI

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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 of yogurt of different flavors via the internet. The yogurt is produced by different machinery all around Germany.

- **Diagnosis of the distributed machinery:** In the event of failure of similar units, 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.

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Case Study: Research Aspects

Requirements

- Configuration of products with interactive resource allocation
- Diagnosis to improve reliability
- Reliable and easy to use by operators
- Flexible and re-configurable in the sense of interoperability, adaptively 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

Source: [Christian Diedrich, OVGU]

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Automation Architecture based on Agents

- Agents are autonomous entities
- Agents achieve goals and may learn
- Agents interact with the environment and other agents

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Examples for Smart Units

“Smart Units“ are dedicated towards special application thereby fulfilling a particular customer value

Intelligent Bus Terminal facilitates signal processing and control

„Intelligent Bin“ requests for a refill on its own

High-precision signal acquisition from strain gauges

Precise strain measurement in the I/O system

Source: Beckhoff

iBin is counting the parts using an integrated camera. The system interacts with the cloud for part logistics

Source: Fraunhofer IML, Prof. Dr. Michael ten Hompel
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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.
“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 1
- Execution layer
  - Image processing with classifier
  - Product recognition
  - Camera-guided robot

Layer 2
- Adaption layer
  - Observation for parameter adjustment (open loop control)

Layer 3
- Optimization
  - Simulation-based optimization upon models (closed loop control)

System target
- Automation system
- Image Processing
- Classifier
- Observer
- Parameter adjustment
- Optimization
- Simulation
- QA

Products / Work pieces
- Sorted Products
Citation of the DFG SPP: Organics Computing

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
Seamless integration of Automation Technology

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

Demonstration of new Technologies
Which technology provide better products or improves the process?

Examples for Value Proposition
Which new value is created based on which technology?

Architecture of Value Creation
What is the best configuration to deliver?

Value add

- Level of maturity / thorough testing
- Dependability / safety
- Easy to use/configure
- Efficient design
- Decentralized control
- Adaptation and learning
- New Functions
- "Project business"
- "Commodity"

Innovative Products with medial complexity of technology and cost effectiveness

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