The German-Czech Innovation Lab MRK 4.0
Smart Industrial Services

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Innovation Lab for Hybrid Human-Robot Collaboration Team (MRK4.0)

- 20 Robots
  - Humanoids, mobile platforms, tele-presence, collaborative robotic arms
- Cooperation with CIIRC (Czech Institute of Informatics, Robotics and Cybernetics)
  - Intelligent Human-Machine-Collaboration in cyber-physical production environments
  - Semantic Technologies for service orchestration and process optimization in Smart Factories
  - Multimodal, proactive und situation aware Production Assistance with VR, AR and Mixed Reality-Technologies
  - Realtime-Production Planning for Industrie 4.0
DFKI‘s Robotics Innovation Center in Bremen

60 Innovative Robots Produced by DFKI for Space, Underwater, Manufacturing, Security
Artificial Intelligence for the Second Wave of Industrial Service Digitalization

First Wave:
Digital Data
- Record
- Save
- Transmit
- Process

Second Wave:
Digital Data
- Understanding
- Refining
- Active Usage
- Monetize

Machine-readable Data:
Internet and Cloud Technologies

Machine-understandable Data:
Artificial Intelligence and Machine Learning
Towards Intelligent Environments based on the Internet of Things and Services

1) Central Computer
   1941
   1 Computer
   Many Users

2) PC, Notebook
   1960
   1 Computer
   1 User

3) Smart Phone
   1980
   Smart Card

4) Embedded Computers
   2000

5) Intelligent Environments
   2020

Many Computers, 1 User

Industrie 4.0

90% of all computers are embedded

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Key Aspects of Industrie 4.0 based on the AI for the IoT

Needs of manufacturing industry …
- Increased efficiency, batch size 1, and multidaptivity required
- Smart Factories are defined by
  - Dynamic networks of local controllers
  - Flexible production configured in response to rapidly changing processes
  - Anytime planning in realtime
  - Optimization of production, e.g. through Cyber-Physical Production Systems
  - Self-organization, e.g. product steers its own way through the production process
  - Digital Twins of the entire process and its constituent elements

… can be clustered into four core aspects

Modularity

Connectivity

Autonomy

Digital Twin

Adapted from Siemens
Outline of the Talk

1. The Basic Concept of Smart Services in the Internet of Things
2. Platforms and Components for Smart Services
3. Use Cases and New Business Models Based on Smart Services
4. Conclusions
The Web of Things as the Jet Engine for Smart Factories, Products and Services

- The Web is essential for realizing the full potential of the IoT.
- The Web provides a unifying framework for semantic interoperability.
- The Web acts as a global marketplace for suppliers and consumers of services.
Injecting AI: AI + Smart Data = Smart Services

Key Features of Smart Services
- Autonomous
- Proactive
- Adaptive
- Self-explanatory
- Interoperable
- Self-healing
- Self-learning
- Self-optimizing
- Fault-tolerant

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Technology Layer Cake for the Smart Industrial Services

- **Service Platforms**: Market Places, App Stores, Web Service Repositories...
- **Software-defined Platforms**: Virtualized Networks, Clouds, Semantic Web, Big & Smart Data Real-Time Analytics...
- **Connected Physical Platforms**: Cars, Manufacturing Equipment, Appliances, Medical Equipment...
- **Technological Infrastructure**: Ubiquitous Internet Access, Sensor Networks, Positioning Systems...

- **Smart Services**
- **Smart Data**
- **Smart Products**
Self-learning Smart Service Architectures Based-on Artificial Intelligence (AI)

Customer
- Personalized and situation adaptive customer experience by AI-based user and context modelling

Smart Service Provider
- Self-learning smart services and AI-based chatbots, recommendation and assistance systems

Platform Operators
- Machine learning for data understanding, AI-based information extraction from non-structured documents

Data Supplier
- Intelligent multi-sensor fusion, AI-based data curation

AI Methods and Tools for the Smart Service Welt
- Machine Learning
- Pattern Recognition
- Language Understanding
- Picture Recognition
- Action Planning
- Plan Recognition
- Inference
App Stores for the Smart Factory
Technology Data Marketplace as a Use Case

Source: Trumpf
Digital Infrastructure for Service Engineering

Service platforms
- Generic modules
- Specific modules

Software-defined platforms
- Service bundles
- Architectural patterns
- Generic enablers

Networked physical platforms

Configuration

Smart services
- Business context
- Organisational structure
- Operational processes

Programming

Smart products

Source: Siemens 2014
The German Vision for Smart Services 2015

- **New business models**
  - e.g. trading of production capacity and manufacturing data

- **Crowd Communities**
  - create manufacturing innovations

- **Cognitive abilities**
  - inform automated activities on site via remote access

- **Fully automated marketplace**
  - for service providers

- **Machines/service providers**
  - actively seek out new jobs

- **Knowledge work**
  - automatic generation of analyses, diagnoses and recommendations

- **Optimisation**
  - continuous generation and automated feedback of empirical data

- **Bundling of services, e.g. finance, insurance**

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**Digital Platforms**

- **Export of smart services**
  - from Germany and Europe

- **Leading platforms are operated**
  - by German and European companies

- **Selected critical modules and enablers**
  - produced by German and European firms

- **Opportunities for start-ups and SMEs**
  - through efficient market access and rapid scalability

- **Smart talents:** employees as creative leaders and decision-makers

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**Smart Machines**

- **All machinery throughout the world connected to platforms**

- **Machines added and removed via „Plug & Use”**

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Source: Siemens 2014
New Value Chain: Smart Data as the Basis for Smart Services

- Business Data
- Product Data
- Service Data

Smart Data Sources

Industrial IoT Platform

Software-defined Platform

Smart Services

- Design improvements
- Machine health monitoring
- Early warnings to prevent downtimes
- Prioritize maintenance and service activities
- Optimized warranty and spare parts mgmt
- Benchmarking
Service Platform Business Models

Vendor Service Platform
„IT Service Provider“

Open Service Platform
„Community Plattform“

Closed Service Platform
„Company X Plattform“

Business Models for the Development and Operation of Service Platforms
Industrie 4.0 Is Supported by 6 Cloud-Based Platforms from Germany for the Industrial IoT
Eco systems provide Apps for the digital market places, which are built in the App Factory Alliance. Each partner keeps their own digital innovation identity to the market. Digital market places are operated on the ADAMOS IoT Platform. Partners can use a market place blue-print to get started faster. Market places are cloud based and have a pricing model „pay per use“ for risk sharing. Small partners without an own market place can use the ADAMOS market place.
ADAMOS ADAptive Manufacturing Open Solutions

APP FACTORY ALLIANCE

APP MARKET PLACE

PARTNER ECO SYSTEMS

ADAMOS GmbH

APP FACTORY ALLIANCE

APP MARKET PLACE

ADAMOS IoT SUITE

NEW

GOVERNANCE
(Standards, Interfaces, …)

adapted from ADAMOS
BaSys: an Open System Architecture for Industrie 4.0 like AUTOSAR for Vehicle Manufacturers

Functional Industrie 4.0 Components

Interface: Middleware Services

Interface: Runtime Services

Interface: Application Environment

BaSys 4.0 Runtime System

BaSys 4.0 Software Abstraction Layer

Hardware and Operating System

Interface: Static Services

Interface: Local Services

Component and Technology Suppliers

Software Base System for Industrie 4.0

Device Level

Lukas, Landvogt, Ruhmann

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Emancipation of Field Devices: Direct Sensor Access from and to the Smart Service Architecture of Industrie 4.0
Check List: Your Way to the Smart Service Welt

Transformation into Smart Service Business

- Are you looking for new revenue streams?
- Can you use your product to collect data?
- Can the functionality of your product be enhanced digitally?
- Do you already collect data about the usage of your product?
- Do you use data from your customer’s usage of your product to improve your business model and product lines?
- Are Smart Services based on Smart Data an essential component of your Company Strategy?
- Do you offer personalized product-service packages?
Active Semantic Product Memories for Industrie 4.0: Digital Twins

Cyber-Physical System (CPS) + Active Semantic Product Memory as a Digital Model

Includes Information about …
- Maintenance
- Context Conditions
- Security
- Location
- Status
- Embedded Components,
- Interfaces
- CO2 Footprint
- Materials
- Handling

The Semantic Product Memory Is Continuously Updated and Serves as a Lifelog of the History of an Individual Product

Product Design > Production Planning > Production Engineering > Production > Smart Services

Source: Siemens
The Structure of the Object Memory Model (OMM, W3C Standardization)
Meta Descriptions for the Semantics of Payloads for Process Owners
Standardization as a Key Success Factor for Industrie 4.0

Interfaces between Digital Enterprise and Digital Factory Layer

Semantic Service Description and Semantic Product Memory
- OWL
- OWL-S
- OMM++
- USDL
- WSDL

DIN EN 62264

ISO

VDI 2860

Communication Standards
- Ethernet
- IP
- OPC UA
- SoA

Standardization through Interoperability
- RJ45, WiFi…
- TCP/IP
- OPC-UA
- IEEE 802.11

Mechatronic Base Standards
- HAN-Modular®

Standardization through Semantic Meta Description Languages

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The Service-Oriented Architecture of Industrie 4.0

Knowledge Base of Semantic Service Descriptions

Service Offers

Service Usage

Service Discovery and Selection

Smart Factory

Context Information

Dynamic Service Orchestration

Abstract Process Description

Smart Product

Concrete Process Description
Key Components of Service-Oriented Cyber-Physical Production Systems

Production Service Discovery, Matching and Execution

Production Pathplanning Based on Semantic Product Memories

- Machine 1: Active Semantic Product Memory
- CNC Milling Machine
- Machine N: Active Semantic Product Memory
- Workpiece Carrier 1: Active Semantic Product Memory
- Emerging Product 1: Active Semantic Product Memory
- Workpiece Carrier N: Active Semantic Product Memory
- Emerging Product N: Active Semantic Product Memory

Semantic Product Memory
- Top Shell Selection
- Circuit-Top Shell Packaging
- RES-COM Engravature
- Top and Bottom Shell Assembly
The Intelligent Workpiece Carrier: A Complex Cyber-Physical System
Service-Oriented Planning of Plant Systems

Hardware-independent planning of plant systems

Service Library

Sensor-Service

Valve-Service

Pump-Service

Control-Service

Communication-Service

Abstract Service

Device Control

ER<br>Enterprise Resource Planning

MES<br>Manufacturing Execution System

Field Layer

Industrie 4.0: All-IP Factories, no chaos of field buses, Internet-based Factory Networking based on IoS and IoT
Semantic Web Services for Industrie 4.0: The Semantic SOA Model of the Smart Factory

Physical Model
- SOA-based Smart Factory
  - Ultrasound Sensor
  - Inductive Sensor
  - RFID-LSG
  - Electronic Stopper
  - Camera

Functional Model
- Function "Fill"
  - "Filling various drugs into individual pill boxes"
- Function "Control quality"
- Function "Detect pill box"
- Function "Count pills"
- Service "Stop pill box"
  - Service "hold"

Service Directory
- Web-Service "stopper"
  - Operation: "hold"
  - IP 192.168.178.29

Services:
- Stopping Unit Services:
  - hold
  - release
  - check
- RFID-LSG Services:
  - read
  - write
- Ultrasound Sensor Service:
  - check
- Camera Service:
  - count_pills

Nach D. Zühlke, DFKI
Smart Service: Design of Individual Gripper by the Customer and Mass Customization via 3D Printing
Three DFKI Professors Hold Leading Positions in the New Large Scale Funding Platform Learning Systems

W. Wahlster (Steering Committee) in charge of enabling technologies
V. Markl (WG Leader) in charge of data science
F. Kirchner (WG Leader) in charge of robots for toxic environments

f.l.t.r.: Andreas Heindl (acatech), Johannes Winter (acatech), Markus Dicks (Federal Ministry of Education and Research (BMBF)), Ralf Klinkenberg (RapidMiner GmbH), Secretary of State Georg Schütte (Federal Ministry of Education and Research (BMBF)), Dieter Spath (President of acatech), Ute Bernhardt (Federal Ministry of Education and Research (BMBF)), Reimund Neugebauer (President of Fraunhofer), Wolf-Dieter Lukas (Federal Ministry of Education and Research (BMBF)) and Wolfgang Wahlster (CEO DFKI)
Matrix Organization of the New German Funding Platform

Steering Committee

WG1: Technology Enablers & Data Science
   Prof. Dr. Volker Markl (DFKI)

WG2: Future of Work & Human-Machine Interaction

WG6: IT Security, Privacy, Legal and Ethical Framework

WG7: Business Model Innovations

WG3: Mobility and Intelligent Transport Systems

WG5: Hostile-to-life Environments

WG4: Health Care, Medical Technology, Care

Prof. Dr. Frank Kirchner (DFKI)

Managing Office
The time has come for Germany to focus more attention on the topic of artificial intelligence. The German Research Center for Artificial Intelligence has become established as the biggest research institute worldwide on this topic. In international comparison our research is outstanding, and the results demonstrate the great potential of this new technology for the economy and society. We must now think about artificial intelligence in new categories and, as is the case with Industrie 4.0, expect that there will be far-reaching change. This is why we want to combine strengths in this forward-looking project and bring about systematic momentum in Germany.

Federal Minister Johanna Wanka
(Federal Ministry of Education and Research)
Conclusions

• Massively multimodal sensor networks form the basis for Cloud-based Industrial IoT Platforms and Smart Services for new applications and disruptive business models in advanced manufacturing and processes in the Industrie 4.0 paradigm.

• Industrie 4.0 brings the Web of Things to the shop floor of factories and allows mass customization of smart products as a platform for new smart services based on instrumented environments.

• Cyber-physical production systems and digital twins enable Plug&Produce and multiadaptive smart factories. Collaborative robots and hybrid teams of robots and human workers are key for low-volume high-mixture factories. Networked sensors form the nervous system of these new paradigms.

• Factory Workers will be assisted by a new generation of collaborative robots and intelligent industrial assistance systems using multimodal dual and augmented reality based on active sensors and AI-based sensor fusion and interpretation.
Thank you very much for your attention.