2nd Networking Meeting: German-Finnish Technology and University Cooperation
Germany and Finnland – Strong Partnership in Industrial Internet Revolution – The Way Forward?
Symposium at Salon Dahlmann, Berlin, November 11, 2016

Industrie 4.0: Mass Customization in Multiadaptive Smart Factories

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Industrie 4.0: The Internet of Things in the Smart Factory

- Capturing Context Information
- M2M Communication Between Intelligent Objects
- Cross-linking of Assets and Products in the Factory Internet
- Digital Product Memories
- Trusted Cloud
- Context-sensitive and Location-Based Smart Services
From Industrie 1.0 to Industrie 4.0: Towards the 4th Industrial Revolution

In 2010, the term Industrie 4.0 was coined by this team.

1. Industrial Revolution through introduction of mechanical production facilities powered by water and steam
   - End of 18th Century

2. Industrial Revolution through introduction of mass production based on the division of labour powered by electrical energy
   - Start of 20th Century

3. Industrial Revolution through introduction of electronics and IT for a further automatization of production
   - Start of 70ies

4. Industrial Revolution based on Cyber-Physical Production Systems
   - 1 April 2011
Towards Intelligent Environments based on the Internet of Things and Services

1) Central Computer
   1 Computer Many Users

2) PC, Notebook
   1 Computer 1 User

3) Smart Phone
   Smart Card

4) Embedded Computers

5) Intelligent Environments

1941 1960 1980 2000 2020

90% of all computers are embedded

Many Computers, 1 User

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Socio-Economic Drivers of Industrie 4.0

- Lack of Skilled Workforce
- Aging Society Later Retirement
- Volatile Markets, Demand up- and down
- Multiadaptive Factories
- Shorter Product Lifecycles
- Increasing Product Variability
- Resource-Efficient and Clean Urban Production
- Batch Size 1, Mass Customization Low-volume High-mixture Factories

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Evolution from Embedded Systems to Cyber-Physical Systems

Future Project Industrie 4.0 of German Chancellor Dr. Angela Merkel

Internet of Things

Intelligent Environments/Smart Spaces
Digital City

Cyber-Physical Systems
Smart Factory, Smart Grid

Networked Embedded Systems
Intelligent Street Crossing

Embedded Systems
Airbag

National Roadmap
Embedded Systems

Agenda
Cyber-Physical Systems
After Our Initial Publication in April 2011 the German Term “Industrie 4.0” was Propagated Exponentially Worldwide

According to GENIOS Data Base of Publications in Germany

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Industrie 4.0: The Fourth Industrial Revolution
Beyond Industrie 4.0: Long-term Autonomy

Beyond Industrie 4.0

- Deep Learning for Long-Term Autonomy
  - Collaborative Robots (30%)
  - Cyber-physical Production Technologies (30%)
  - Web of Things (20%)
  - Industrial Internet (20%)

100%
The Adidas Speedfactory: Bringing Sports Shoes Production back to Germany by Industrie 4.0 for Mass Customization

- The costumers can design their own short shoes using an App.
- Since the customer wants to receive his personalized product on the next day or faster, long logistic chains from low-wage countries are no longer acceptable in the era of mass customization.
- Thus, adidas decided to open various "speedfactories" for personalized shoes in Germany close to the customer, using Cyber-physical production systems (CPPS).
From Manual Production via Mass Production to Mass Customization

„People can have the Model T in any color – so long as it's black.“
Henry Ford (1913)

Based on: The Global Manufacturing Revolution; sources: Ford, beetleworld.net, bmw.de, dw.de
Onshoring in Industrie 4.0 vs Offshoring in Industrie 3.0

- High-wage Countries
- Industrie 4.0
- Mass Customization
- Short and Mobile Chains to Consumers in Europe
- Small Networked Smart Factories

- Low-wage Countries
- Industrie 2.0 - 3.0
- Mass Production
- Long and Complex Logistic Chains to Consumers in Europe
- Big Traditional Factories

For example: sport shoes, clothes, kitchens, appliances, consumer electronics, toys, bikes…
The Retrofitting of Legacy Factories with an Additional Layer of Cyber-Physical Systems

Raspberry PI 1
CPS as an Active Product Memory for the Emerging Product

WLAN Router

Classical SPS

Raspberry PI 2
CPS for Processing Sensor Data from the Additional Sensor Web

MICA CPS
Thousands of CPS 4.0 Form the Nervous System of a Smart Factory

In Industrie 4.0, conventional field devices and SPS (Storage Programmable Systems) will be replaced by thousands of CPS 4.0 interconnected via industrial internet protocols.
The Semantic Factory Memory: A Graph Database for Relations Between Employees, Machines, Products, Processes, and Tools

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Products with Integrated Dynamic Digital Storage, Sensing, and Wireless Communication Capabilities

⇒ The product as an information container
  – The product carries information across the complete supply chain and its lifecycle.

⇒ The product as an agent
  – The product affects its environment

⇒ The product as an observer
  – The product monitors itself and its environment

I was produced on 30 April 2010 and shipped on 3 May 2010

Grasp at the middle

2 mins open
Please close!
The Structure of the Object Memory Model (OMM, W3C Standardization)
The Smart Keyfinder with its Semantic Product Memory Chip

Semantic Product Memory Chip in the backcover plastic frame with product specification

Bluetooth circuit board with key-finder logic packaged inside a plastic shell

Personalized keychain with custom metal tag on the front produced by an engraving machine
The Service-Oriented Architecture of Industrie 4.0

Knowledge Base of Semantic Service Descriptions

Service Offers
Service Usage
Service Discovery and Selection

Dynamic Service Orchestration

Context Information
Concrete Process Description

Smart Factory

Abstract Process Description

Smart Product

Concrete Process Description
Key Components of Service-Oriented IoT Production Systems

Production Service Discovery, Matching and Execution

Production Pathplanning Based on Semantic Product Memories

Semantic Product Memory
- Top Shell Selection
- Circuit-Top Shell Packaging
- RES-COM Engravature
- Top and Bottom Shell Assembly
The Intelligent Workpiece Carrier: A Complex CPS

The Taxi to Production Services
Plug&Produce based on Adaptive Service Ontologies

- Plugin of CPS production components on a physical, digital and semantic level

- Automated Expansion of the Service Ontology

New Assembly Component is installed on-the-fly
Dynamic Planning Based on Service Composition in a SOA Architecture for Smart Factories

Green Production
Minimize CO2

Abstract
Process
Specification

Plug & Produce

Conveyor1.transport
(lowSpeed)

Pick&Place.insertBottom
(AssemblyPlace4)

Pick&Place.insertBoard
(AssemblyPlace4)

Pick&Place.insertCap
(AssemblyPlace4)

AssemblyPlace4.compress
Semantic Description of all Factory Components as Services in OWL-S Ontology
Standardization as a Key Success Factor for Industrie 4.0

- **Standardization through Semantic Meta Description Languages**
  - Semantic Service Description
  - Semantic Product Memory
    - OWL
    - OWL-S
    - OMM++
    - USDL
    - WSDL

- **Interchange between Digital Enterprise and Digital Factory Layer**
  - DIN EN 62264

- **Standardization through Interoperability**
  - Communication Standards
    - 7. SOA Services
    - 6. OPC UA
    - 5. IP
    - 4. TCP/IP
    - 3. RJ45, WiFi...
    - 2. Ethernet
    - 1. HAN-Modular®

- **Mechatronic Base Standards**
  - DIN 2860
  - VDI 2860

- **Interoperability Standardization as a Key Success Factor for Industrie 4.0**
DFKI’s Multi-Vendor Smart Factory in the Industrie 4.0 Paradigm
Seamless Interoperability, Multiadaptivity, and Plug&Produce

Manual Workstation  Weighing Module  Quality Control  Laser Marking  Robot Module  Force Fitting  Production  Engraving  Storage Module

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IoT Technologies in the Smart Automation Line of Bosch-Rexroth at Homburg

Cooperation with DFKI and the Power4Production Center in the SmartF-IT Project

Source: Bosch-Rexroth
Advanced Industrial Assistant Systems Based on Augmented Reality Technologies

Industrial Environment

Industrial Worker with Data Glasses

Tools

Mobile, Interactive and Situation-Aware Tutoring
Look-Through Technology Used in the Smart Factory
The Spin-Off Company IOXP of DFKI has revolutionized the Workflow for AR Presentations
Industrie 4.0: Robots are no Longer Locked in Safety Work Cells but Cooperate with Human Workers

The Past

A new generation of light-weight, flexible robots collaborate with humans in the smart factories of DFKI.

The Future

AUDI

BMW
Intelligent Human-Robot-Collaboration in the Smart Production Lab of VW in Cooperation with DFKI
The Collaborative Robot APAS provides the worker with the right screw type according to the workflow.

The use of the screwdriver (which is connected via Internet to the CPS middleware) is monitored by ultrasonic sensors.

Collaborating APAS Robot

Monitoring of Screwing
Bosch‘s APAS Cobot in DFKI‘s SmartF-IT Assembly Line with an Internet-Enabled Screwdriver (ZeMA)
Hybrid Teams: Robots Collaborate with Humans in Physically Challenging Overhead Assembly Tasks (Hybr-iT)

Hybr-iT Architecture
Middleware, Simulation, Reference Architecture for Assistant Systems and Knowledge-based Features

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BaSys: an open system architecture for Industrie 4.0 like AUTOSAR for vehicle manufacturers
The Anatomy of BaSys 4.0

- **Factory Level**
  - Network
  - Gateway
  - Comprehensive Process View

- **Virtual Middleware**
  - Aggregated Components
  - Information about Workpieces and Workflow
  - Semantic Product Memories as Digital Twins

- **Device Level**
  - Factory Memory
  - Sensors and Actuators
  - Device
    - APP
    - Operating System
    - HW Platform
    - APIs

- **Design Environment**
- **Engineering Environment**
- **Runtime Environment**

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MindSphere: Siemens-SAP Cooperation on Industrie 4.0 Cloud Platform

Optimization of plants and machines as well as energy and resources

- **Open standard (OPC)** for connectivity of Siemens and third-party products
- **Plug and play connection** of Siemens products (engineering in the TIA Portal)
- **Cloud for industry** with open application interface for individual customer applications
- Optional **cloud infrastructure** – public cloud, private cloud or on-premise solution
- **Transparent pay-per-use pricing model**
- Opportunities for completely new **business models** (e.g. selling machine hours)

powered by

SAP HANA

- Simatic
- Sinumerik
- Sinamics
- Scalance
- PCS7
- Third-party products
New Joint Innovation Laboratory MRK4.0 for Human-Robot Collaboration in Industrie 4.0

Czech PM Bohuslav Sobotka and Chancellor Dr. Angela Merkel at the signing ceremony with Prof. Marik and Prof. Wahlster in Prague

Investment Grant for Equipment Lightweight Robots and Wearables 1 Mio. €

Living Lab for Support of Small and Medium Enterprises

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The Web of Things as the Industrie 4.0 Jet Engine for Smart Factories, Products and Services

Take-away Lessons:

• 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 industrial services.
Helping SME’s during the transition phase to Industrie 4.0

Core Centers selected in First Round in 2015

Secondary Centers selected in 2016

First Smart Factory Living Lab founded in 2005
Conclusions

• Industrie 4.0 is a success story of a strategic public-private partnership and secures Germany's economic power as a leader in manufacturing.

• Industrie 4.0 brings the Web of Things to the job floor of factories and allows mass customization of smart products for a reasonable price based-on semantic technologies and semantic service matchmaking.

• Cyber-physical production systems and semantic product memories 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.

• Factory Workers will be assisted by a new generation of collaborative robots and intelligent industrial assistance systems using multimodal dual and augmented reality.

• Systems based-on long-term autonomy and deep learning go beyond Industrie 4.0 and enable autonomous smart factories.
Thank you very much for your attention.