Industry 4.0: From Smart Factories to Smart Products

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From Industry 1.0 to Industry 4.0: Towards the 4th Industrial Revolution

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

First Mechanical Loom
- 1784

Degree of Complexity
- Industry 1.0
- Industry 4.0

18th Century
From Industry 1.0 to Industry 4.0: Towards the 4th Industrial Revolution

1. Industrial Revolution
   through introduction of mechanical production facilities powered by water and steam

2. Industrial Revolution
   mass production based on the division of labour powered by electrical energy

First Mechanical Loom
1784

End of 18th Century

Start of 20th Century

Degree of Complexity

Industry 1.0

Industry 2.0

Industry 4.0
From Industry 1.0 to Industry 4.0: Towards the 4th Industrial Revolution

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

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

3. **Industrial Revolution**
   - Through electronics and IT and heavy-duty industrial robots for a further automation of production
   - **Start of 70ies**

Degree of Complexity

- **Industry 1.0**
- **Industry 2.0**
- **Industry 3.0**
- **Industry 4.0**

Towards the 4th Industrial Revolution
From Industry 1.0 to Industry 4.0: Towards the 4th Industrial Revolution

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 further automation of production
   - Start of 70ies

4. Industrial Revolution based on Cyber-Physical Production Systems
   - today

Degree of Complexity

Industry 1.0
Industry 2.0
Industry 3.0
Industry 4.0
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

Industry 4.0

90% of all computers are embedded

Many Computers, 1 User

1941 1960 1980 2000 2020
500 M€ for 3 Years
National Program:
250 M€ Funding of
Ministry for Research and
Ministry for Economics

**Evolution** from
Embedded Systems
to Cyber-Physical
Systems

Future Project Industry 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
CPPS: Based on Wireless Adhoc M2M Communication of Autonomous Sensor-Actuator Components

1. Component-based Automation
2. Efficient Reconfiguration
3. Context-sensitive Component Behaviour
4. Dynamic Adaptation Based on Individual Role of the Component

Industry 4.0: Smart, Green, and Urban Production

Smart Production
High-precision, superior quality production of high-mix, low volume smart products

Green Production
Clean, resource-efficient, and sustainable

Urban Production
Smart Factories in the city close to the employees’ homes
The Internet of Things and Services as a Basis for the Smart Factories in the Industry 4.0

Internet of Services

Semantic PLM-, SCM-, CRM-, QMS- and ERP-Services

Smart Factory

Cyber-Physical Production System

Smart Material

App Platform

Smart Products

App Platform

Internet of Things
Pipelines of Smart Factories for Industry 4.0 based on Secure Networks of Clouds

Smart Factory 1

Smart Machine 1

…

Smart Machine N

M2M-Communication

Application Platform for Machines

Cyber-Physical Production Systems CPPS

Secure Cloud Networks

Smart Materials

Smart Products
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
Service-oriented planning of plant systems

Hardware-independent planning of plant systems

ERP
Enterprise Resource Planning
MES
Manufacturing Execution System

Field Layer

Abstract Service
hardware-independent

Device Control
hardware-dependent

Industry 4.0: All-IP Factories, no chaos of field buses, Internet-based Factory Networking based on IoS and IoT
From Bits and Bytes to Semantics

 driven by

 Electrical Engineering

 driven by Software Engineering

Via functions

To semantic services

common ontology

knowledge based

Semantic Technologies

driven by
The SmartFactory Shop Floor: Wireless, RFID-, Sensor- and Service-based Architecture

- **continuous flow process**
  - colored soap production

- **discrete handling process**
  - bottling, handling, labeling, QC, packaging...

Live Webcam: [http://www.smartfactory.de/webcam.de.html](http://www.smartfactory.de/webcam.de.html)
Data Mining and Knowledge Discovery in Smart Factories

Manufacturing stores more data than any other industrial sector. Close to two exabytes of new data were stored in 2010 from multiple sources:

- instrumented production machinery
- supply chain management systems
- product life-cycle systems

New ICT Coordination Action of EU:
BIG: Big Data Public Private Forum
Human-Centered CPS-based Assistance Systems for the Smart Factory

- Physical Assistance by Exoskeletons
- Mobile, Personalized, Situation-Adaptive, Tutoring Systems
- Location-based Maintenance and Planning Assistance
- Multimodal Human-Machine Interaction
- AR/VR/DR-Assistance in Complex Work Processes
- Context-adaptive Assistance for Fault Diagnosis
Key Features of the Next Generation of Industrial Assistance Systems for CPPS in Industry 4.0

- Non-intrusive
- Mobile
- Multimodal
- Location-based
- Personalized
- Context-adaptive

Industrial Assistance Systems
Combining all Senses -
Getting Rid of Keyboard and Mouse in Factories

Speech

Graphics

Gesture

Multimodal Interaction

Eyetracking

Physical Action

Facial Expression

Body Language
App Stores for the Smart Factory: Downloading Tailored User Interfaces for User Groups: Elderly, Trainees, Disabled, Supervisors…
Location-based Industrial Assistance Systems for Smart Factories: Precise Indoor Positioning
Advanced Industrial Assistant Systems Based on Augmented Reality Technologies

Industrial Environment

Industrial Worker with Google Glasses

Tools

Mobile, Interactive and Situation-Aware Tutoring
Augmented Reality Systems Supporting Maintenance Staff
Affordable Industrial Assistant Systems Using Mass Market ICT Components

- **Apps**
  - OTA Download of Pluggable Interfaces

- **Pads, Tabs, SmartPhones**
  - Mobile, Light-Weight

- **Kinect and Sensors in SmartPhones**
  - Inexpensive Gesture Recognition

- **LTE for mobile High-Speed Internet Access**
  - 50-100MBit/s with Data Flatrates

- **CloudNets**
  - for Inexpensive Access to HPC and Mass Storage

- **All IP**
  - Getting Rid of Industrial Fieldbuses

- **Industry 4.0**
Industry 4.0: Robots are no Longer Locked in Safety Work Cells but Cooperate with Human Workers

Today

Tomorrow

A new generation of light-weight, flexible robots collaborate with humans in the smart factory
AILA: DFKI’s Fembot can be teleoperated or cooperate autonomously in a joint task as an assistant to a factory worker
DFKI’s Fembot AILA: Using the Semantic Product Memory for Adaptive Grasping and Smart Product Assembly

Stereo Cameras in the Head and a 3D Camera on the Torso for Approaching an Object

Reading Size, Weight and Lifting Points from the Product Memory with an antenna in the left hand – the Robot gets instructions from the product being produced in the CPPS
W3C Standards as a Basis for the Project of the Future Industry 4.0

EMMA: Multimodal Industrial Assistance Systems

Industry 4.0
Smart Factory

OMM: Semantic Product Memory

USDL: Semantic Services in Cyber-Physical Production Systems
The Software-defined Car: Customizing a Car Environment through Apps

Android Market
Motor Management Apps
Driver Assistance Apps
Intelligent User Interface Apps
Green Driving Apps

App Store

© DFKI GmbH
BMW Apps: Integrating the Most Recent Web Services Into the Car Environment

Source: BMW
Conclusions

1. **High-precision, superior quality production of high-mix, low volume smart products** are the future of Europe’s successful export-oriented economies like Germany and especially the Saarland or Luxembourg.

2. **80% of the innovations** in manufacturing are based on ICT. They will lead to Smart Factories, Green and Urban Production.

3. **The fourth Industrial Revolution** will be based on cyber-physical systems, the Internet of Things and the Internet of Services. It will generate enormous BIG data streams that can be harvested and analyzed for resource-efficient production.

4. **CPS-based industrial assistant systems** are needed to support, help and train the next generation of workers in smart factories.

5. **Augmented and dual reality systems** allow individualized workflows and fast learning of new production processes.
Thank you very much for your attention.