CDL-Flex in the Context of Industrie 4.0 at TU Wien

Christian Doppler Laboratory
Software Engineering Integration for Flexible Automation Systems
Dec. 13, 2016

Institute for Engineering Design and Logistics Engineering
Manufacturing Informatics and Virtual Product Development Research Group
Univ.-Prof. Dr.-Ing. Detlef Gerhard  ■  http://www.mivp.tuwien.ac.at
Introduction
- Production Initiatives
- Smart Production
- Internet of Things (IoT)
- Cyber-Physical Systems (CPS)

TU Wien Activities
- Doctoral College “Cyber-Physical Production Systems”
- Pilotfabrik Industrie 4.0
- Innovationslehrgang DigiTrans 4.0
- K1 Center for Digital Production

Conclusion
Introduction: IT in the Product Creation Process

- Domain-Spanning **Product Development Methods** for
  - Mechatronic Products and Systems, Cyberphysical Systems (CPS)
  - Product-Service-Systems PSS

- IT systems as essential parts of innovative and complex products

- IT tools supporting tasks and processes in development processes

- **IT-Tools for Virtual Product Creation Process**
  - e.g.: CAx, Calculation, Analysis, Simulation, Visualisation
  - **Industrial Information Systems**, i.e.: PDM/PLM, ERP, MES, ...
Importance of Production in EU

» Industry is a central pillar of the European economy – the EU manufacturing sector accounts for 2 million companies and 33 million jobs.

Our challenge is to ensure that all industrial sectors make the best use of new technologies and manage their transition towards higher value digitized products and processes, commonly known as "Industry 4.0".


manufacturing added (% of GDP), 1995 - 2014

Net job creation in manufacturing in the Member States (2007-12; in thousands)

"The EU-commission wants to reverse “the shrinking role of the industry” and restore the “attractiveness of Europe as a production location”"

Antonio Tajani (2012) (former) European Commissioner for Industry and Entrepreneurship
European Initiatives on “Digitising” Industry

**EU-level initiatives**
- Application Public Private Partnerships: Factories of the Future (FoF), Sustainable Process Industry (SPIRE)
- ICT Innovation for Manufacturing SMEs (I4MS)
- Smart Anything Everywhere
- Digital Sector Public Private Partnerships – ECSEL, Photonics, Robotics, High Performance Computing (HPC), Advanced 5G networks for the Future Internet (5G), Big Data Value PPP

**Multi-region Initiatives**
- Vanguard
  - United Kingdom
    - High Value Manufacturing Catapult
    - Innovate UK
    - EPSRC Manufacturing the Future
    - Action Plan for Manufacturing (Scotland)
  - Belgium
    - Made Different
    - Flanders Make/Minds (Flanders)
    - Marshall 4.0 (Waalonia)
  - France
    - Nouvelle France Industrielle
    - Industrie du Futur
    - Transition Numérique
    - Le Programme des Investissements d’Avenir
    - Plan Industries Ile-de-France

**Regional Initiatives**
- Portugal
  - PRODUTECH
- Spain
  - Industria Conectada 4.0
  - Basque Industry 4.0 (TECNALIA)
- Italy
  - Internet of Things and Industry 4.0
  - Fabbrica Intelligente Ass. Fabbri. Intell. Lombardia
- Sweden
  - Produktion 2030
- Denmark
  - MADE
- Netherlands
  - Smart Industry (NL)
- Finland
  - FIMECC PPP Programmes
  - DIGILE
  - TEKES
- Latvia
  - Demola (Riga IT TechHub)
- Poland
  - INNOMED
  - INNOLOT
  - CuBR
  - BIOISTRATEG
- Germany
  - Plattform Industrie 4.0
  - Mittelstand 4.0
  - Smart Service World
  - Autonomik fur Industrie 4.0
  - It’s OWL (Ostwestfalen-Lippe)
  - Allianz Industrie 4.0 (Baden-Württemberg)
- Slovakia
  - Smart Industry (SK)
- Czech Republic
  - Průmysl 4.0
- Austria
  - Produktion der Zukunft
- Greece
  - Operational Programme in Region Western Greece

Source: Lemke 2016, DG CONNECT
A possible vision of Industrie 4.0…
‘[…] availability of all relevant information in real-time by connecting all entities contributing added value as well as the ability to deduce the ideal added-value-flow at all times. […]’.


Source: Roland Berger: Industry 4.0 – How Europe will succeed:
http://www.rolandberger.de/media/pdf/Roland_Berger_TAB_Industry_4_0_20140403.pdf
Cyber-Physical Systems (CPS)

- Cyber-Physical Systems typically consist of **Embedded Systems** (as part of devices, buildings, cars, traffic infrastructure, **production systems**, logistics components etc.), which
  - Capture (physical) data with **sensors** and act on their environment with **actors**
  - Are **connected** to digital data networks (wireless, wired, local, global)
  - Use Internet Services and **Cloud** Technologies
  - Comprise several **multi-modal** Human Machine Interfaces (HMI) (specific devices, browser based, etc.)
- What are the main characteristics of CPS?
  - Context sensitive/ adaptive
  - (Partly) autonomous

**Source:** Broy, TUM
# Smart Connected Products

## Capabilities of Smart, Connected Products

The capabilities of smart, connected products can be grouped into four areas: monitoring, control, optimization, and autonomy. Each builds on the preceding one; to have control capability, for example, a product must have monitoring capability.

<table>
<thead>
<tr>
<th>Monitoring</th>
<th>Control</th>
<th>Optimization</th>
<th>Autonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sensors and external data sources enable the comprehensive monitoring of: the product’s condition, the external environment, and the product’s operation and usage. Monitoring also enables alerts and notifications of changes.</td>
<td>2. Software embedded in the product or in the product cloud enables: control of product functions, personalization of the user experience.</td>
<td>3. Monitoring and control capabilities enable algorithms that optimize product operation and use in order to: enhance product performance, allow predictive diagnostics, service, and repair.</td>
<td>4. Combining monitoring, control, and optimization allows: autonomous product operation, self-coordination of operation with other products and systems, autonomous product enhancement and personalization, self-diagnosis and service.</td>
</tr>
</tbody>
</table>

Smart Production
Technologies driving the change

IoT (physical meets digital)
Embedded software, sensors, connectivity, actuators, low power ICT, ...

Big data (value from knowledge)
Analytics, storage, Cloud HPC, ...

Innovation in products, processes and business models

AI (autonomous systems)
Robotics, automation, machine learning, self-driving, ...

Source: Lemke 2016, DG CONNECT
TU Wien Industrie 4.0 Initiatives

TU Wien
Initiative zu Industrie 4.0

DigiTrans 4.0
Weiterbildung

Industrie als Bildungspartner
Forschung
Innovation

Cyber-Physical Production Systems
Doctoral College TU Wien

Pilotfabrik
Industrie 4.0
Doktoral College CPPS - Research Scope

PhD Topic 1
Cloud Manufacturing

PhD Topic 2
Productivity- and Employment-oriented
Working System Design in CPPS

PhD Topic 3
Virtual Engineering Design of CPPS

PhD Topic 4
Modeling of CPPS

PhD Topic 5
Support for the Multi-Disciplinary
Engineering of CPPS

PhD Topic 6
Smart Attributes for CPPS

PhD Topic 7
Reactive Cyber-Security for CPPS
Communication”

PhD Topic 8
Industrial Internet

PhD Topic 9
Communication at High Data Rates in
Harsh Production Environments”

PhD Topic 10
Cell Controller Design for Robotized
Manufacturing Cells in the Smart Factory

Process Layer

Abstraction Layer

Physical Layer

Methods

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Doctoral College CPPS - Key Faculty

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*CDL-Flex*

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Institute of Information Systems
*Distributed Systems Group*

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*Cyber Physical Systems Group*

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*Business Informatics Group*

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Institute of Telecommunications
Prof. Dr. Tanja Zseby
*Communication Networks Group*

Prof. Dr. Friedrich Bleicher
Institute for Production Engineering and Laser Technology
*Machining Tools and Cutting Technologies*

Prof. Dr. Detlef Gerhard *(Speaker)*
Institute for Engineering Design and Logistics Engineering
*Mechanical Engineering Informatics Group*

Prof. Dr. Wilfried Sihn
Institute of Management Science
*Industrial and Systems Engineering Group*
Cyber Physical Production Systems (CPPS)

Enabling Technologies
- Sensors
- Actors
- Cloud Services
- Wireless & Mobile Communication
- ...

Self-X Functions
- Communication & Negotiation
- Interpretation & Decision
- Configuration & Adaptation
- Analysis & Optimization
- ...

Cyber Space
- Quality
- Availability
- Energy Demand
- Quantity
- Energy Supply
- Dates
- Errors
- Ressources
- ...

Real Space
- supplier
- Engineering
- Production
- Customer

Lifecycle (Product und Production System)
- Development
- Production
- Usage/Operation
- Disposal

Virtuality
- Visualization
- Simulation
- Reality

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Automation Pyramid - From Signals to Services
Fields of Action for CPPS

- **Vertical Integration:** Capturing vast amounts of data by sensors within the lifecycle phases production and usage. Processing and analytics on all levels of the automation pyramid (ISA 95)

- **Horizontal Integration:** Usage of the product as information carrier within the whole process chain (lifecycle) from the first manufacturing and steps up to maintenance and service (e.g. “Digital Product Memory”)

- **Assistance:** Support of workforce on all levels of the production process by provision of context sensitive information (e.g. „Augmented Operator“)

- **Coherent Existence of Virtuality and Reality:** Multi-disciplinary modelling of product and production system and coherent representation of Virtuality and Reality
TU Wien Pilot Factory Industrie 4.0

- Platform for Research and Demonstration
- Investment ca. 4 Mio € in the next 2 years
- Flexible and adaptive automation
- Holistic virtualisation („Digital Twin“)
- Assistant systems for production and assembly
One process-spanning example
- Parts Manufacturing (subtractive, hybrid)
- Assembly
- Material flow, Intra-logistics
for Industrie 4.0 issues

Why?
- Mechatronic product
- Configurable (variants)
- Adequate complexity
- Moderate material requirements
- „Sales“ opportunities

But:
- Only one demo example!
5 structural layers
~200 BOM positions
~45 different parts

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<th>Stücklisteneintrag</th>
<th>Anzahl</th>
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Strengthening competitiveness through ...
- New innovative power and competence
- New cooperation (knowledge generation and skill transfer)
- Tight feedback loop between academia and industry
DigiTrans 4.0 - Concept

- Crossover Lectures for cross innovation
- Domain spanning and integrative modules
- Theory, practical courses, and multiplication at industrial partners
"Composable" Production Systems
Conclusion

- CPS provide the option to create and operate production systems in a way, that they are **more resource efficient, agile, and flexible** in order to ensure competitiveness for companies in the production sector
  - Cognitive technical **assistant systems** for production
  - **Real Time** collection/sharing of sensor data on all levels
- **Holistic modelling of complex technical systems** becomes crucial in mastering complexity of products and production systems
  - Classic CAx modelling is not sufficient since function, logic, and behaviour modelling is missing
  - Integration of “operational phase” in modelling aspects is important
  - Definition of “boundaries” of self-x capabilities is a challenge
- The **human** - given the creativity, intelligence, and problem solving competence - will remain in the **centre** of future flexible and adaptive production systems >> education & skill development/transfer
  - Develops and engineers product and production system
  - Plans, controls and supervises production on the basis of real time information on all levels
- **CPPS** mainly address “Operational Excellence” - **Disruptive changes** will take place on business model level rather than on operational level
Dass Maschinen miteinander kommunizieren, ist ok
Aber jetzt tusheln sie mit dem Betriebsrat