EXPERIENCES FROM APPLYING CYBER-PHYSICAL SYSTEMS (CPS) IN PRODUCTION AND LOGISTICS

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Agenda

- Introduction
  - Background / Motivation
- What is “Industrie 4.0”?
  - What's the role of CPS / CPPS?
- Cases from applied research
- Conclusions
BIBA is an engineering research institute and does research in the field of production and logistics.

BIBA is an affiliated institute of the University of Bremen.

BIBA researches and develops technical and organisational solutions and implements them in practice-oriented businesses.

The staff at BIBA comes primarily from production engineering, industrial engineering, engineering and management, computer science, electrical engineering and other related disciplines.
The University of Bremen

- Foundation in 1971 - 45 years of University of Bremen
- Interdisciplinary and practice orientated studies based on specific projects - „Bremen Model“
- Single „University of Excellence“ in the north-west of Germany
- 137 Bachelor- and Master courses
- 20,000 Students and 290 professorships
- 12 faculties
Research Cluster for Dynamics in Logistics

- 24 Working Groups
- LogDynamics Lab
- Doctoral Training Group
- LDIC Conference Series
Short note on Bremen: Past ...

www.bremenflug.de

www.wikipedia.org

www.wikipedia.org

www.wikipedia.org, by Emoscopes

www.wikipedia.org, by John Conway

www.bremerhaven.de
... and present.
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Fields of Research

- (One of a kind Production)
- Customer Driven Manufacturing
- “Collaborative Production”
- “Autonomous Cooperating Logistic Processes”
- Product Service (Eco-) Systems („Extended Products“)
- Collaborative Networks / Innovation / Ecosystems
- Closed Loop Product Lifecycle Management („Product Avatar“)
- …
Evolution of Production

Source: Yoram Koren “The Global Manufacturing Revolution” (modified by FhG)
Towards „Industrie 4.0“

- **Start of 1800s**
  - Mechanical production facilities powered by water and steam.
  - **Industry 1.0**

- **Start of 1900s**
  - Mass production based on division of labor and powered by electrical energy.
  - **Industry 2.0**

- **Start of 1970s**
  - Introduction of electronics and IT for further automation of production.
  - **Industry 3.0**

- **2014 +**
  - Production based on cyber-physical systems.
  - **Industry 4.0**

(Source: Cognizant, Informed Manufacturing: The Next Industrial Revolution)
Domains of Industry 4.0

- Medical
- Logistics
- Traffic
- Energy
- Home
- Production
The ‘Industrie 4.0‘ research programme aims to enable German industry to be prepared for tomorrow‘s production

Keep Germany a manufacturing country

Industrial production will be characterized by strong individualization of products …

in a highly flexible mass production environment, …

integrating customers and business partners in value adding processes to a large extent and …

the integration of production and high level services.”
Aspects of Paradigm shift for Production

- Items deliver their own production data (through identification and life-cycle information).
- Variants are “self-determined”.
- Intelligent items are aware of the environment, exchange information and control processes in production and logistics themselves (machines are able to access processing information from the item etc.).
- Decentralized data storage enables local decisions (decentralized control).
- Highly flexible processes enable individualized mass production.
- New processes can be easily implemented.
- Data is transparent, also when exchanged with partners, and is collected along the whole life-cycle in large quantities.
- ...
Integration of IoT and Production

Cyber-Physical Systems

Human-Robot Interaction

Smart Factory

Business Models / Services

Automation

Internet of Services

Internet of Things

Source: BITKOM
Cyber-Physical Systems

- Merge of **physical and virtual world**
- **Systems of systems** with dynamic borders
- Context-aware, **self-governed**, real-time control
- **Collaborative systems**, distributed control
- **Human-system interaction**
Industry 4.0 causes changes for employees, technology and organizations in production and logistics scenarios:

- Complexity of socio-technical systems will increase.
- Technology as an enabler of new services in the field of logistics.
- Intelligent assistance systems enable employee new scope in the workflow.
- …

How to transform these challenges into (new) applications?
Dialogue of Science and Industry

Competence and transfer center for CPS in logistics

- Development a representative spectrum of Cyber-Physical System modules for production and logistics systems
- Creation of the technical and methodological basis for the economic operation of Cyber-Physical Systems in real production environments.
- Deployment and transfer strategies
- New business models

http://www.biba.uni-bremen.de/industrie4.html
Transfer- and Competence Center on Industrie 4.0 (actual research issues with CPS relation)

Use of CPS data for construction
- Digitization of interplant material flows
- Autonomous unloading of containers
- Highly flexible handling technology
- Digitization of internal material flows

Business Model

Apprenticeship / Further Training
- Safe human-robot interaction
- Quality control by image recognition
- Automatic control of logistic processes
- Decentralized testing
- State-based distribution
- Preacting maintenance
- Recycling / Refurbishing

Serious Gaming

Business Model innovation

Additional Information: [http://www.biba.uni-bremen.de/industrie4.html?&L=1](http://www.biba.uni-bremen.de/industrie4.html?&L=1)
New automation potentials for industrial processes

- **Example technologies investigated at BIBA**
  - Deep learning in combination with 2D/3D vision technology
  - Industry 4.0 technology simulation
  - Cellular Conveyor

- **Example application areas in logistics**
  - Automated container unloading
  - Warehouse automation
  - Flexible and modular material flow systems
# Deep Learning – BIBA projects

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<th>Robotics</th>
<th>Warehouse Automation</th>
<th>Production</th>
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<tr>
<td><strong>Process</strong></td>
<td>Unloading of containers with unknown objects</td>
<td>Intelligent forklifters can detect people and infrastructure</td>
<td>Recognition of objects in complex material flows</td>
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<td><strong>Sensor technology</strong></td>
<td>2D/3D Vision</td>
<td>2D/3D Vision</td>
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<td><strong>Benefit</strong></td>
<td>Increasing process efficiency</td>
<td>Increasing safety in warehouses</td>
<td>Increasing energy efficiency</td>
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<td><strong>Image</strong></td>
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Industry 4.0 Technology Simulation

- Interactive sensor simulation software based on a common game engine
  - 2D and 3D Vision
  - RFID
- Virtual logistics environments with dynamic objects
  - Robots, forklifts, humans, pallets, …. 
- Sensor configurations can be tested in advance in a virtual logistics environment
AUTOMATIC UNLOADING OF CONTAINERS
CELLUVEYOR – CELLULAR CONVEYOR

- Highly flexible conveying and positioning system
- Modular architecture
- Omnidirectional
  - movement of any number of objects
  - in arbitrary paths
  - simultaneously and independently from each other
- Complex intralogistics tasks with a compact machine footprint
- Parallel processing
Partly decentralized control
- minimal cabling labour
- automatic recognition of layout
- automatic fault detection

Quick-coupling system for module linkage
- ergonomic
- simple layout change
- fast replacement of faulty modules

Modular support structure (with feet or wheels)

Frameless
CELLUVEYOR – CELLULAR CONVEYOR

- Conveyor
- Aligner
- Outward transfer
- Case turner
- Merger
- 90° and 180° transfer
- Singulator
- Switch or cross sorter
- Sorter
- Layer descrambler
- Infeeder for palletizer
CELLUVEYOR – CELLULAR CONVEYOR

Infeeder for palletizer

Quelle: Uni-Tech
CPS in Production Logistics

- Concepts for improving production logistics by CPS
  - Integration of CPS into products, parts and logistics resources
  - Support for demand-oriented production supply (e.g. “Milkrun 4.0”)  
  - Holistic synchronisation of material and information flows
  - Automated Kanban approach suitable for mass-production environments – 30% better efficiency

- CPS-based optimization of “high and heavy” logistics processes
  - Tracking and tracing heavy load carriers in harbour environments with Auto-ID and positioning technologies
  - Complimentary inventory strategies
    - Carrier request time reduction
    - Optimisation of traffic flow
  - CPS-based optimisation of container handling
CPS-based Preactive Maintenance

- CPS allow for dynamic adjustment of maintenance process to particular needs under cost-/risk considerations
  - Mining task-relevant information from maintenance-related CPS data
  - Support corrective maintenance tasks by early failure prediction/recognition
  - Components which exhibit a linear wear-out curve should be evaluated by cost-risk and scheduled e.g. together with other tasks
  - Operative executions of tasks by context and based on multi-criteria aspects
  - On mid-term level a continuous improvement of the system will be enabled
    - Increased availability and reliability of production assets and products
    - New business models for maintenance servitization

Corrective maintenance
- Replace after it breaks
- Lead to unplanned stops
- High maintenance costs

Preventive maintenance
- Replace before it breaks
- Planned stops
- Wear margin not fully used

Preactive maintenance
- Failure prediction and replacement of the component just before the breakdown
- Fewer / shorter planned stops
- High availability and lower costs

Number of unplanned stops

Aim:
1 planned visit per year and 4 unplanned stops
Symbiotic Safe Human-Robot Interaction

- CPS can increase the potential for the use of robots
  - Potential for an increase in productivity by enabling robot to work in close proximity or together with workers

- Solutions for safe human-robot interaction
  - Advanced sensor technology and computer vision provide a first layer of safety
  - CPS integrated into work clothes help monitor and predict body and limb movement
  - Intelligent algorithms connected to robot control
  - Touch-sensitive robots can be guided intuitively by workers for precision control of heavy parts in complex processes

- Robots will be true partners of the worker in the shipyard
- More flexible application of robots

Conventional safety solution

Symbiotic safety solution

Source: kranendonk.com/

Source: Bayreuth University

Source: InSA
Conclusion

- Focus on understanding of processes and technologies
- Control of complexity to integrate new technologies and services
- Strong focus on integration / interface competencies ("Cross-domain", "Cross-discipline", “multilevel“ interoperability)
- Strengthening dialogue of science and industry
- …
Many thanks for your attention!

Contact

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