Toolbox for the efficient implementation of Industrie 4.0 based on use cases

Prof. Dr.-Ing. J. Fleischer
Tokyo, 26th October
Agenda

1. Introduction
2. Successful implementation of Industrie in Small and Medium Enterprises
3. Toolbox Industrie 4.0
4. Use of the toolbox and examples
5. Summary
Introduction

What has changed?

- People have a 24/7 access to the Internet and all services linked to it.
- Available Internet bandwidth increases, along with the computing power of end devices.
- Mobile devices with Internet access have spread rapidly.
- New business models based on data generate high turnovers and replace traditional business models.
  → E.g. Amazon, UBER, WhatsApp, WeChat.

Many developments and technologies have not yet entered the industry. Where are the potentials and challenges?

Bildquellen: huffingtonpost.ca
Introduction

Enablers, challenges and chances for Industrie 4.0

- **Enabler of Industrie 4.0**
  - Decline of prices of key components e.g. in the area of sensor technology, data storage, computing power of computers
  - Increasing availability of the internet, its technologies and standards
  - Increasing acceptance of “new” technologies by society

- **Challenges of Industrie 4.0**
  - Industrie 4.0 is no value as such
  - Industrie 4.0-technologies are an enabler for the implementation of new ideas

- **Chances of Industrie 4.0**
  - New products
  - New business models
  - Efficient production processes

Bildquellen: Classic Key Icon, Esteban Sandoval; Puzzle Icon, Joao Proenca; Money Plant Icon, Aha-Soft; thenounproject.com
Introduction

Industrie 4.0 Pyramid

Service
- Development of business activities through services
- Example: Condition Monitoring as a service

Connectivity
- Network, middleware and communication
- Example: Communication between manufacturing systems

Devices / Systems
- Systems with integrated analysis of sensor data
- Example: Adaptive systems, intelligent gripper

Sensors / Actuators
- Influences on process and evaluation of process data
- Example: vibration sensor
Industrie 4.0 Direction of development

- "Physicalize the Cyber"
  - Application of IT within manufacturing

- "Cyberize the Physical"
  - Increased usage of IT within manufacturing

Connectivity

Service

Devices / Systems

Sensors / Actuators
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Challenges and Potentials

**Challenges of Industrie 4.0:**
- Classification of own competencies and the company strategy within the area of Industrie 4.0
- Identification of application areas for valuable use-cases
- Use of the opportunities of Industrie 4.0 for new products or increased production efficiency

**Potentials of Industrie 4.0:**
- Better satisfaction of customer needs
  → Increase in sales!
- Increase in internal manufacturing efficiency
  → Increase in competitiveness!

**Industrie 4.0 cannot be bought, the success of the 4th industrial revolution has to be earned!**
How can valuable use cases be reached?

**Potentials**

**Market requirements:**
- New Products
- Efficient production

**Resources/Strengths**

**Own competencies:**
- Related to Industrie 4.0

**Filtering-Process**

Ideas for new products, services or an increase in process efficiency

Ideas for new products, services and an increase in efficiency have to be designed individually in a systematic process.

Bildquelle: Box Icon, Maximilian Becker; Factory Icon, Laurent Patain; Weight Lifting Icon, James Keuning; thenounproject.com
The successful Implementation of Industrie 4.0

Potentials: Production

- Which approaches lead to an increase in production efficiency?
  - Minimization of Input
  - Maximization of Output

- Which new technologies are able to support an efficient design of the production process?

Industrie 4.0 is only useful if it generates an added value. Market requirements and potentials have to be considered in the process of developing innovations.
The successful Implementation of Industrie 4.0

Own Resources and Strengths

- Where is the company’s know-how and where are the competencies?
- Where can existing experiences with applications of Industrie 4.0 be found within the company?

Examples for already existing competencies:

**Competencies in products**
- Ability of products to communicate
- IT-based services
- Integration of sensors
- Evaluation of sensor data
- ...

**Competencies in production**
- Collection and evaluation of operating data
- Communication within production
- Usage of ergonomic human-machine interface
- ...

Existing competencies have to be considered and expanded while realizing new ideas. The focus on own competencies helps with the realization of ideas.

Bildquelle: Weight Lifting Icon, James Keuning; thenounproject.com
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Overview

- The Toolbox Industrie 4.0 provides a classification of own competencies and is an incubator for new ideas.

- The Toolbox is subdivided into two areas:
  - **Products** (Development of new products)
  - **Manufacturing** (Development of production)

The Toolbox Industrie 4.0 is a support tool for the classification of competencies and for the creation of new ideas in the area of Industrie 4.0.
Toolbox Industrie 4.0

Toolbox Products

- **Application level:**
  - Integration of sensors/actuators
  - Communication/Connectivity
  - Functionalities for data-storage and information exchange
  - Monitoring
  - Product-related IT-Services
  - Business models around the product

![Diagram showing integration of sensors/actuators, communication/connectivity, functionalities for data-storage and information exchange, monitoring, product-related IT-Services, and business models around the product.](image_url)

*Quelle: Leitfaden Industrie 4.0, VDMA*
Toolbox Industrie 4.0

Toolbox Manufacturing

- **Application level:**
  - Data analysis in production
  - Machine-to-Machine-Communication (M2M)
  - Companywide networking with the production
  - ICT-Infrastructure in manufacturing
  - Human-Machine-Interface
  - Efficiency in small production batches

Toolbox Industrie 4.0

<table>
<thead>
<tr>
<th>Toolbox Industrie 4.0</th>
<th>Industrie 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production</strong></td>
<td></td>
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<tr>
<td>Data processing in the production</td>
<td>No processing of data</td>
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<tr>
<td></td>
<td>Storage of data for documentation</td>
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<td></td>
<td>Analyzing data for process monitoring</td>
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<td></td>
<td>Evaluation for process planning / control</td>
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<tr>
<td></td>
<td>Automate process planning / control</td>
</tr>
<tr>
<td>Machine-to-machine Communication (M2M)</td>
<td>No communication</td>
</tr>
<tr>
<td></td>
<td>Field bus interfaces</td>
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<td></td>
<td>Industrial ethernet interfaces</td>
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<tr>
<td></td>
<td>Machines have access to internet</td>
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<tr>
<td></td>
<td>Web services (M2M software)</td>
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<tr>
<td>Companywide networking with the production</td>
<td>No networking of production with other business units</td>
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<tr>
<td></td>
<td>Information exchange via mail / telecommunication</td>
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<td></td>
<td>Uniform data formats and rates for data exchange</td>
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<tr>
<td></td>
<td>Uniform Data formats and interdivisionally linked data servers</td>
</tr>
<tr>
<td></td>
<td>Interdivisional, fully networked IT solutions</td>
</tr>
<tr>
<td>ICT infrastructure in production</td>
<td>Information exchange via mail / telecommunication</td>
</tr>
<tr>
<td></td>
<td>Central data servers in production</td>
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<td></td>
<td>Internet-based portals with data sharing</td>
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<td></td>
<td>Automated information exchange (e.g. order tracking)</td>
</tr>
<tr>
<td></td>
<td>Suppliers / customers are fully integrated into the process design</td>
</tr>
<tr>
<td>Machine interfaces</td>
<td>No information exchange between user and machine</td>
</tr>
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<td></td>
<td>Use of local user interfaces</td>
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<td></td>
<td>Centralized / decentralized production monitoring / control</td>
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<td></td>
<td>Use of mobile user interfaces</td>
</tr>
<tr>
<td></td>
<td>Augmented and assisted reality</td>
</tr>
<tr>
<td>Efficiency with small batches</td>
<td>Rigid production systems and a small proportion of identical parts</td>
</tr>
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<td>Use of flexible production systems and identical parts</td>
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<td>Flexible production systems and modular designs for the products</td>
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<td></td>
<td>Component-driven flexible production of modular products within the company</td>
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<tr>
<td></td>
<td>Component-driven, modular production in value-adding networks</td>
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</table>

Quelle: Leitfaden Industrie 4.0, VDMA
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### Use of the toolbox

**Toolbox Industrie 4.0**

<table>
<thead>
<tr>
<th>Products</th>
<th>Integration of sensors / actuators</th>
<th>Communication / Connectivity</th>
<th>Functionalities for data storage and information exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>No use of sensors/actuators</td>
<td>The product has no interfaces</td>
<td>No functionalities</td>
<td>Possibility of individual identification</td>
</tr>
<tr>
<td>integrated</td>
<td>The product sends or receives IO signals</td>
<td>Possibility of individual identification</td>
<td>Product has a passive data store</td>
</tr>
<tr>
<td>product</td>
<td>The product has field bus interfaces</td>
<td>Product has a passive data store</td>
<td>Product with data storage for autonomous information exchange</td>
</tr>
<tr>
<td>product</td>
<td>The product has industrial Ethernet interfaces</td>
<td>Product with data storage for autonomous information exchange</td>
<td>Data and information exchange as integral part</td>
</tr>
</tbody>
</table>

**Application of the Toolbox using the example of a ball screw**

- **1. Integration of sensors / actuators**
  - No use of sensors/actuators

- **2. Communication / Connectivity**
  - The product has no interfaces

- **3. Functionalities for data storage and information exchange**
  - No functionalities

- **4. Inductive Lubrication**
  - The product sends or receives IO signals

**Quelle:** Leitfaden Industrie 4.0, VDMA; Steinmeyer Gruppe
Detection of demand for lubricant in ball screws

Maintenance of ideal friction torque in ball screws for temporally constant conditions

Lubrication Algorithm:

- Combination of simulation and measurement
- **Continuous comparison** of measured real and simulated ideal values of ball screw friction torque
- Simulation is **metrologically adapted** to the specific condition of each ball screw
  - Correction factors in simulation model [Fle-14]
- Implementation in LabView
- The algorithm calculates ideal friction torques for **constant operating conditions**

**Actual friction torque** ($t_n$)

**Comparison:**
Comparison between actual and simulated friction torque

**Friction model:**
Simulated ideal friction torque ($t_n$)

**Decision**

Reliable lubrication algorithm due to a combination of measurement and simulation.
Test rig and Equipment

- **Test rig with 8 substantive ball screws**
  - 4 spindles with 2 ball screw nuts each
  - Every nut has its own travel range
  - Two nuts per spindle connected by rods
    - **Constant load & revolution**

- **Customized torque-sensing capsules**
  - Torque-sensing capsule for every nut
  - Accuracy 0.02 Nm

- **Temperature sensors**
  - Every nut exterior and spindle-temperature
  - Thermosensitive Pt100-elements
  - Accuracy 0.2 °C

Detection of actual friction torques via measurement system
**Results**

**Use of the toolbox**

### Results of lifetime tests

- **Small amounts of grease for relubrication**
  - Avoid over-supply
  - Tested ball screws 32x5
    - Best practice adaptive: 250 mg
    - Manufacturer’s Recom.: 2000 mg

- **Increased lifetimes due to Adaptive Lubrication**
  - Average increase of 70 %
  - Failure criterion: solid residues in grease

- **Reduced energy demand** due to reduced fiction

- **Overall grease-amount only 30 %** compared to standard lubrication

### Graph

![Bar chart showing nominal lifetime comparison between Standard Lubrication and Adaptive Lubrication](chart.png)

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<thead>
<tr>
<th></th>
<th>Average lifetime</th>
<th>Coefficient</th>
</tr>
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<tr>
<td>Standard Lubrication</td>
<td>257 %</td>
<td>1</td>
</tr>
<tr>
<td>Adaptive Lubrication</td>
<td>439 %</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Adaptive Lubrication increases lifetime and reduces demand for energy and lubricant**
Use of the toolbox

DMG: Celos

- Product:
  - Universal user interface for machine tools
  - Platform for new services
  - Integrated administration, documentation and visualization of order, process and machine data

- Added value of the product:
  - Time saving through direct access to data
  - Improved usability
  - Premium prices for machine manufacturer
  - Time saving for user
Use of the toolbox

Rolls Royce: Total Care

- **Product:**
  - Jet engine is provided together with its monitoring, maintenance and repairing for the whole lifecycle of the product
  - Jet engine remains property of Rolls Royce
  - The airlines are paying for the function of the jet engine

- **Added value of the product:**
  - Financial risks can be reduced
  - Operating costs become projectable
  - The availability of the jet engines increases
  - Action steps for improvements are conducted

Quelle: Rolls Royce PLC, : Leitfaden Industrie 4.0, VDMA
Use of the toolbox

Bosch Rexroth: Multiproduktionslinie

- Improvement in manufacturing:
  - Equipping work pieces with RFID-chips for identifying and displaying specific operating instructions for the personnel
  - Assembly line for manufacturing more than 200 versions of hydraulic valves

- Added value of improvement:
  - The complexity of high variant diversity becomes manageable for personnel
  - High productivity despite small batch sizes
  - Realization of continuous assembly concept for increasing productivity with high variant diversity

Quelle: Bosch Rexroth AG, Leitfaden Industrie 4.0, VDMA
Use of the toolbox

ARBURG: „Intelligent“ parts

- Improvement in manufacturing:
  - Wide application of DMC on physical parts
  - Access to production data with mobile devices
  - Input of the data and analysis by superior planning algorithm

- Added value of improvement:
  - Parts are trackable and identifiable
  - Dynamic control of production
  - Increasing efficiency and competitive advantages

Quelle: ARBURG GmbH + Co KG, : Leitfaden Industrie 4.0, VDMA
Use of the toolbox

Concept for joint workshop

- **Objectives of the workshop**
  - Identify and show Industrie 4.0 cases in Japanese industry
  - Discuss potentials and risks for Industrie 4.0 in production
  - Derive common understanding and further activities for collaboration

- **Four target questions**
  - Do we need a toolbox for Japan or is the shown toolbox applicable? What needs to be altered in the shown toolbox for Japan?
  - What are examples of digitalization or Industrie 4.0 in Japan?
  - What are common issues between Germany and Japan for further cooperation in the field of Industrie 4.0?

- **Approach**
  - Discussion of the target questions and the described use cases
  - Identification of key factors and barriers as well as further activities for collaboration
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Summary

- Effects on products and manufacturing environment
  - Sensors and actuators extend the physical world and are a link to the digital world
  - Future products and production will be able to communicate
  - Services expand the functions of products

- Industrie 4.0-Technologies
  - Many technologies are already available
  - Added value is created by connecting already existing technologies intelligently

- Realization of Industrie 4.0
  - Only through implemented Use-Cases benefits can be revealed

- Industrie 4.0 benefits component life time by smart and adaptive lubrication enabled by I4.0 technologies
Thank you for your attention!