Evaluation of Information Technology for „Industrie 4.0“ Production systems

25. Oktober 2016, NOKIA-Lectures at University of Stuttgart

Project Team
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Agenda

- "Industrie 4.0"
- Expected Contribution of Information Technology
- On how to measure the Impact of IT
  - A Model of IT "Abilities"
  - Key Performance Indicators
  - Identification of Value Patterns
- Conclusion
High expectations in „Digitalisation“
Considering the globalization trend, new work and production approaches need to be conceived to shape the inevitable change ...

2014: New York Times Bestseller “how digital technology is transforming our work and our lives”

2014: „78 Billion Euro adding value till 2025“

2015: „390,000 new jobs in Germany till 2025“

[4, 5]
Value-adds in Production are driven by IT
+++ fast launch of new products +++ fully utilize manufacturing equipment +++ manage peak loads +++ cover up supply chain issues +++ follow customer requests +++ adjust production +++ be efficient ++++

“In the manufacturing environment, vertical networking, end-to-end engineering and horizontal integration … is set to usher in the fourth stage of industrialisation – INDUSTRIE 4.0”.

Acatech and Forschungsunion: Recommendation for implementing the strategic initiative INDUSTRIE 4.0, April 2013
The scenario envisions a highly flexible mass production, which can produce even a one-of-a-kind type of products by means of automated manufacturing in a highly efficient way.

What difference can IT make in „Industrie 4.0“?

Deployment of Information Technology

- Extension of state-of-the-art automation
- Game changer for future automation

Mass production with the goal to decrease production costs

State-of-the-art IT utilizing conventional IT in industrial production

“One-of-a-kind” Production with valuable individualisation for customers

Hypotheses: shift in economic “Mass Customization” secures the innovation lead in manufacturing

[1]
Mass Customisation

“... to offer products or services which meet the demands of each individual customer, but are produced by means of industrial mass manufacturing ...”

Example: Individual Watches

Example: Taylor made shoes

http://frankpiller.com/mass-customization/

Source: http://customiser.bamfordwatchdepartment.com/customise_tag_monaco-REVISE.cfm
Visualization of „DIE ZEIT“: “Cyber Physical Production” of the Future
Research ambitions and Value-add Claim of “Industrie 4.0”
IAS Analysis (2015): The Value-Adds are very generic and reflect the various research ambitions in manufacturing automation and IT of the past decades.

Research Ambitions

Value-add Claims

[1]

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What makes the IT flavor of “Industrie 4.0” and “Cyber-physical Systems”? From processing of distributes big data, Men-machine interaction, new control approaches to autonomous systems.

[1]
„Industrie 4.0“ Map of Germany

The map shows more than 250 (Oct. 2016) practical use-cases which are in an early stage of development.

- **Mainly:** “Decision Support and Assistance systems” for automated manufacturing
- **Also:** „Solutions for Energy Efficiency“, „Predictive/Preventive Maintenance“, „Changeable manufacturing systems“ and „Adaptive Logistics“

[6, 7]
How to measure and evaluate the value adds of “Industrie 4.0” Manufacturing and “Cyber Physical Production Systems”?
Foresight based on an “advanced scenario method”

Identifies IT Abilities and related Performance indicators which leads to value patterns. (Methodology: known from macroeconomics for trend analysis in economy [8])

- Provides a framework for analysis, projection and simulation
- Group discussions of experts
- Literature surveys

Evaluation Model for a cyber physical system

Value Pattern / Value Add

Based on

Abilities

Based on

Enabling Technologies

Based on

Performance Indicators

Based on

Metrics

Literature surveys

[1]

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[1]
Abilities aim to provide a descriptive model explaining cyber-physical production systems from a technological viewpoint.

Def. Ability: is necessary for the exchange of information

Communication Ability

Wireless Products

→ New product alliances for Bluetooth, ZigBee, EnOcean, etc

Standard Fieldbuses

→ Large number of wired bus systems
  → CAN
  → Ethernet
  → ProfiBus
  → FlexRay
  → USB
  → ...

Routing

→ New routing technologies and protocols (e.g. MPLS, ATM, RPSTL, etc.)
→ Software defined networking
→ Research on ad hoc networks (e.g. DFG SFB 368)
→ ...

Networking

→ Quality of Service
→ Semantic communication standards
→ ...
The Ability Model is leading to a “Score Card” for Evaluation

Eight different abilities along with a refined scoring system can be used to assess the impact of IT in an automated manufacturing system

- Data processing ability
- Integration ability
- Communication ability
- Basic Abilities: Capture and processing of data and information
- Perception ability
- Knowledge creation ability
- Reasoning ability
- Cognitive Abilities with a flavor of artificial intelligence
- Generalization
- Specialization
- Characteristics of distributed systems

[1]
„Model Car“ Smart Manufacturing of IAS (1 of 2)
IAS has developed a Smart Factory using latest information technology.

Modular Assembly System

Reconfigurable Units

Configurable Product
„Model Car“ Smart Manufacturing of IAS (2 of 2)

The automatic manufacturing system addresses a number of “Cyber Abilities”, by means of sensors, RFID, distributed micro controllers and agent-based control algorithms.

- **Data processing ability:** Level 2 – „Real time, decentralized“
- **Communication ability:** Level 2 – „Wireless“
- **Integration ability:** Level 4 – „Objects managed as Entity“
- **Perception ability:** Level 2 – „Detect objects in the environment“
- **Knowledge creation ability:** Level 0 – „none“
- **Reasoning ability:** Level 2 – „Algorithms based on rules“
- **Generalization ability:** Level 0 – „none“
- **Specialisation ability:** Level 2 – „Partially autonomy of Modules“
Foresight based on an “advanced scenario method”

Identifies IT Abilities and related Performance indicators which leads to value patterns. (Methodology: known from macroeconomics for trend analysis in economy [8])
Usage of Key Performance Indicators (KPI)

KPI measure how well an organization is making progress in achieving a particular objective.

KPI in manufacturing are well established, e.g. the Overall equipment effectiveness (OEE).

How would KPI help assessing Information technology deployed?

[1]
Measurable Performance Indicators

As a result of the KPI analysis, it is evident that there are different types of measurable characteristics.
Event-discrete Simulation

Conducting an Automatic reconfiguration is analyzed in simulation
Various abilities such as data processing, communication, perception, and reasoning improve the production rate and productivity.

**Simulation: Cost analysis**

- **A1** → **B1** → **C1**
- **A2** → **B2** → **C2**
- **A3** → **B3** → **C3**

**Strategy**

**Conventional systems:** The “wait for repair” strategy is realized in the simulation.

**Cyber physical system:** The “conducting an automatic reconfiguration” strategy is realized in the simulation.

**Alternatives:**

- **MODULE FAILURE:**
  - Reconfiguration: 100€
  - Wait for repair: 200€
  - Outsourcing: 300€

**Total costs of production:**

- **Conventional systems:**
  - Wait for repair: 200€

**Cyber-Physical:**

- Reconfiguration: 100€

**KPIs**

- **Production Rate**
- **Revenue**
- **Productivity**
Verification in the Simulation (2 of 2)

The failed module must realize ("Perception") its failure and be able to inform the products ("communication") which then has to interact to find the next station ("data processing")

Simulation: Quality analysis

Conventional systems:
- low-quality parts are dropped and lost

Cyber physical system:
- compensating for a moderate quality loss by reworking

Strategy

Quality: 80%

Due to failure of the painting station the quality drops by 20 %.

As the product realizes that there is an issue in quality with C1, it will choose it will go to an undisturbed station for rework.

KPIs

Production Rate

Productivity

GoodPartRatio

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Evaluation Model for a cyber physical system

Value Pattern / Value Add

Abilities Based on

Enabling Technologies

Based on

Performance Indicators

Based on

Metrics

[1]
Value Patterns of „Industrie 4.0“ / „Cyber-physical Systems“

Interconnection between performance indicators and abilities reveal the four patterns which are the important aspects of the evaluation model.

<table>
<thead>
<tr>
<th>Pattern 1 - “Smart Modules”</th>
<th>Pattern 2 - “Interoperability and Self-configuration”</th>
<th>Pattern 3 – “Self-optimization”</th>
<th>Pattern 4 - “Decision Support”</th>
</tr>
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<table>
<thead>
<tr>
<th>Modularity</th>
<th>Communication Ability</th>
<th>IT Integration Ability</th>
<th>Automatic Adaption</th>
<th>Automatic Planning</th>
<th>Reconfigurability</th>
<th>Ability of Automatic Scheduling</th>
<th>Complexity</th>
<th>Maintainability</th>
<th>Knowledge Creation and Reasoning Ability</th>
<th>Social Interaction</th>
<th>Support of Decisions</th>
<th>Perception Ability</th>
<th>Data Processing Ability</th>
<th>Production Efficiency</th>
<th>Perfpormance Indicators, characteristics and related CPPx Abilities</th>
<th>According to Fig. Grouping of Abilities and further Aspects of a CPPx</th>
<th>According to Fig - Classification of measurable Indicators</th>
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Legend:

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Pattern 1 - “Smart Modules”

The performance indicator of Modularity is clearly driven by two technical abilities; the Communication Ability and the IT Integration Ability.

- Flexible machinery is built-up from models
- Functions are distributed in a network
- All participating modules are interconnected
- Communication happens between all participants

[1] Bildquelle: Anna Salari, designed by freepik
Pattern 2 - “Interoperability and Self-configuration”:
A production module or system can be used in numerous different contexts and modified to a new configuration of hard- and software itself.

Systems changeability happens all the time and is enabled by interoperability:

- Interoperability between modules requires a standardized communication

- „Industrie 4.0“ Assets are indirectly defined by their administration shell

- Standardization activities are on their way

[1]
Value Patterns 3 and 4

**Pattern 3 – “Self-optimization”**

If a system is able to perceive its own status and process related data, it can improve its own operational performance leading to Self-Optimization

**Pattern 4 - “Decision Support”**

The processing of networked data and information would support any decision making. It can be viewed as social interaction related to the provision of information

[1]
Conclusion and Outlook

- Information Technology will change automation and knowledge processing once again
- "Industrie 4.0" has managed to set the topic of "Automation" on the political agenda
- Big Gap between Industry relevant technology and future approaches
- Trans-disciplinary cooperation required between the Information technologies, Computer Science and mechanical / production engineering

- "Industrie 4.0" is a long way to go ...
References


(3) Acatech and Forschungsunion: Recommendation for implementing the strategic initiative INDUSTRIE 4.0, April 2013


(6) Landkarte Industrie 4.0: http://www.plattform-i40.de/i40/Navigation/DE/In-der-Praxis/Karte/karte.html


Vielen Dank!

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