4.0, Digitalization, Innovation: From Distributed Artificial Intelligence and Cognitive Computing towards Trends and Future Changes in Work, Life, and Society

Arbeit 2020: Faire Arbeit im digitalen Wandel
Ministerium für Arbeit, Integration und Soziales NRW
September 1st, 2016
Univ.-Prof. Dr. rer. nat. Sabina Jeschke
IMA/ZLW & IfU
Faculty of Mechanical Engineering
RWTH Aachen University
Outline

I. Introduction
   - Breakthroughs in Artificial Intelligence...
   - ... and a networked world
   - Back to the future: the rediscovery of cybernetics

II. Innovation
   - Who makes innovations? – The vendor change in 4.0
   - What are innovations? – From the basics to innovation in 4.0
   - How to innovate? – About innovation cultures in 4.0

III. From organic to cognitive computing
   - What is cognitive computing?
   - ... Addressing problems of “human-like” complexity
   - ... Copying human thought processes
   - ... Intuitive intelligent interaction with humans...

IV. Summary and Outlook
... leading to the 4th industrial (r)evolution...

**Breakthroughs - A new era of artificial intelligence**

- **Communication technology**
  - bandwidth and computational power

- **Embedded systems**
  - miniaturization

- **Semantic technologies**
  - information integration

**Google Car** 2012

**Watson** 2011

→ **Systems of “human-like” complexity**
... leading to the 4th industrial (r)evolution...

Breakthroughs - Everybody and everything is networked

Communication technology
bandwidth and computational power

Embedded systems
miniaturization

Semantic technologies
information integration

Swarm Robotics

Team Robotics

Smart Factory

Car2Infrastructure

Smart Grid

01.09.2016
S. Jeschke
The fourth industrial (r)evolution
“Information Revolution”

Everybody and everything is networked. - Big Data & Cyber-Physical Systems

“Internet of Things & Services, M2M or Cyber Physical Systems are much more than just buzzwords for the outlook of connecting 50 billions devices by 2015.”
Dr. Stefan Ferber, Bosch (2011)

Vision of Wireless Next Generation System (WiNGS) Lab at the University of Texas at San Antonio, Dr. Kelley

Weidmüller, Vission 2020 - Industrial Revolution 4.0
Intelligently networked, self-controlling manufacturing systems

around 1750
1st industrial revolution
Mechanical production systematically using the power of water and steam

around 1900
Power revolution
Centralized electric power infrastructure; mass production by division of labor

around 1970
Digital revolution
Digital computing and communication technology, enhancing systems’ intelligence

today
Information revolution
Everybody and everything is networked – networked information as a “huge brain”
... towards a networked world
Not restricted to industry: cyber physical systems in all areas

Back to: The earth converted into a huge “brain”... (Tesla 1926)

Integrating complex information from multiple heterogeneous sources opens multiple possibilities of optimization: e.g. energy consumption, security services, rescue services as well as increasing the quality of life.

- Building automation
- Smart grid
- Room automation
- Smart metering
- "house 4.0"
- "power grid 4.0"
- "mobility 4.0"
- "health 4.0"
- "education 4.0"
- Smart metering
- "room 4.0"

"metering 4.0"

... and more
... leading to the 4th industrial (r)evolution...

And how do these systems work?

**Communication technology**
- bandwidth and computational power

**Embedded systems**
- miniaturization

**Semantic technologies**
- information integration

?? Steering - Controlling ??

Towards intelligent and (partly-) autonomous systems AND systems of systems

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Innovations in 4.0
The vendor change around „cars“

Characteristics of Industrial Revolutions: The vendor change

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Car specialists? – No.
- Connectivity & data specialists.
- Energy & sensor specialists.

Around 1750
Around 1900
Around 1970
Today

Latest version of Google’s self driving car (Huffington Post, 28.5.2014)
Sony announced autonomous car in 2015, based on their experience in visual sensors
Ford 021C concept car 2012, designed by Newson now at Apple (1999)
Google: First autonomic car with street license, 2012
Sony: First autonomic car with street license, 2012
Tesla X 2015, other Teslas since 2006; Forbes: “most innovative enterprise”

Google Inc.
Apple Inc.
Tesla

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Tesla X 2015, other Teslas since 2006; Forbes: “most innovative enterprise”

Google announced autonomous car in 2015, based on their experience in visual sensors

An autonomous car is more like a computer on wheels than a car which includes one or many computers.

Around 1750

Around 1900

Around 1970

Today

Google Inc.

Apple Inc.

Tesla

Sony

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Innovations in 4.0

The two ways of innovation

Innovations are divided into two categories:

- Evolutionary innovations (continuous or dynamic evolutionary innovation) that are brought about by many incremental advances in technology or processes and
- Revolutionary innovations (also called discontinuous innovations) which are often disruptive and new.

IMPORTANT:
- In times of Industrial Revolutions, the revolutionary innovations dominate.
- In the times between, the evolutionary innovations dominate.
From the Basics to Innovation in 4.0

The innovators’ dilemma

Revolutionary innovations:
- Something “really new”
- Characterized by categorial changes and with strong consequences for the society, ‘globally’
- Mainly carried out by market newcomers

Evolutionary innovations:
- Improvement and optimization of an already existing product or process
- Changes ‘locally’
- Mainly carried out by established players

The more professional organization are, the stronger they tend to remain in their traditions since...
- ... management structure is organized in such a way that it “reproduces” itself
- ... clients’ suggestions always address traditional ways
- ... self-affirmation feedback...

Standard management methods as TQM, CIP(KVP), Kaizen, standards, lean management, etc. address evolutionary processes

- ... hampering categorial changes, system changes and disruptive changes

By C. M. Christensen, 1997 new edition 2015
Since the 1960s:
- research on organizational cultures in respect to innovation, “innovation culture”

Breakthrough of the “culture concept” in the 1980s

Hofstede’s “cultural dimensions theory” (1980)
- 5 cultural dimensions
- Still most cited European social scientist
- Critics addresses mainly the particular dimensions and the measurement process, but not the general approach.

Organizational culture...
- ... transfers the concept of culture from cultural anthropology (national cultures) to organisations.
- ... represents the collective values, beliefs and principles of organizational members.
- ... is a product of such factors as history, product, market, technology, and strategy, type of employees, management style, and national culture.

Hofstede (1991):
Culture is the collective programming of the mind which distinguishes the members of one group from another.

Innovation culture:
Innovation culture describes a specific type of organisational culture addressing the generation of innovation in the organisation.

[Wikipedia, 2015]
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IV. Summary and Outlook
Dealing with complexity

Human machine interaction and cooperative robotics

Robots are no longer locked in work-cells but cooperate with each other and/or with humans.

Robotics entering the scene as:

Cognitive computing is about „solving real problems“. Real problems are usually part of our real, physical world...

The enhancement of AI is strongly connected to the progress in robotics, coupled by the embodiment theory.
Advantage of decentralized control structures

Intralogistics goes mobile: The Festo Logistics League

Mobile transportation robots from flexible routing

Competencies:
- localization & navigation
- computer vision
- adaptive planning
- multi agent strategies
- sensory & hardware

Competitions robocup:
- 2012: 0 points in World Cup
- 2013: 4th in World Cup
- 2014: Winner of the GermanOpen
  2014: Winner of the World Cup
  2015: Winner of the World Cup
  2016: Winner of the World Cup

Critical factors for success:
- Totally decentralized
- No ”hard coded components“
- Strong cooperation
- Re-planning during tasks

http://www.carologistics.org/
Central terms in the field of intelligent distributed systems

From embodiment ... to humanoids

Embodiment theory: „intelligence needs a body“

The existence of a body (incl. sensors and actuators) are basic prerequisites to build experience and finally the development of intelligence.

The Bongard robot – learning through embodiment [Bongard, 2006; Lipson, 2007]


Embodiment theory: „different bodies = different intelligences“

... leading to humanoids/humanoid components

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Lend the robots a face
Into Service Robotics: The next step – the “Oscars”

Transform mobile robotic experiences into the field of service robotics

1. Investigating “new” human machine interfaces and interaction schemes
   - Simple, intuitive
   - Schematic eyes following you
   - “natural eyes behavior”: randomly looking around, showing interest by blinking, looking bored, ...

2. Investigating the “Uncanny Valley”: when features look almost, but not exactly, like natural beings, it causes a response of revulsion among the observers (Mori 1970)

3. Investigating diversity specific reactions (gender, age, culture) to artificial systems and in particular robots
New forms of human machine interaction

About the role of emotion in human-machine-interaction

Plato (ca. 400 BC)
“Human behavior flows from three main sources: desire, emotion, and knowledge.”

However, it took a while before emotions were considered important in computer science.

Rosalind Picard (since 1997; MIT)
“Computers that will interact naturally and intelligently with humans need the ability to at least recognize and express affect.”

Picard coined the term “affective computing”

KISMET - MIT (1990-2000; Cynthia Breazeal)
- Analysis and simulation of human-like emotions
- Research on interaction between robots and humans
- Part of the “organic development”
Let’s ask Google
Definitions around “Cognitive Computing”

“Cognitive computing (CC) makes a new class of problems computable. It addresses complex situations that are characterized by ambiguity and uncertainty; in other words it handles human kinds of problems. ...To do this, systems often need to weigh conflicting evidence and suggest an answer that is “best” rather than “right”. Cognitive computing systems make context computable.”

“Cognitive computing systems [are] a category of technologies that uses natural language processing and machine learning to enable people and machines to interact more naturally [...]. These systems will learn and interact to provide expert assistance to scientists, engineers, lawyers, and other professionals in a fraction of the time it now takes.”

“Cognitive computing is the simulation of human thought processes in a computerized model.... involves self-learning systems that use data mining, pattern recognition and natural language processing to mimic the way the human brain works.”

Copying human thought processes

Intuitive intelligent interaction with humans...
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IV. Summary and Outlook
Go originated in China more than 2,500 years ago. Confucius wrote about it. As simple as the rules are, Go is a game of profound complexity. This complexity is what makes Go hard for computers to play, and an irresistible challenge to artificial intelligence (AI) researchers. [adapted from Hassabis, 2016]

The problem: $2.57 \times 10^{210}$ possible positions - that is more than the number of atoms in the universe, and more than a googol times ($10^{100}$) larger than chess.

Bringing it all together!

Training set
30 million moves recorded from games played by humans experts

Creating deep neural networks
12 network layers with millions of neuron-like connections

Predicting the human move
(57% of time)

Learning non-human strategies
AlphaGo designed by Google DeepMind, played against itself in thousands of games and evolved its neural networks; Monte Carlo tree search

March 2016:
Beating Lee Se-dol (World Champion)
AlphaGo won 4 games to 1.
(5 years before time)

Achieving one of the grand challenges of AI
“Creativity is a phenomenon whereby something new ... is formed. The created item may be intangible (such as an idea, a scientific theory, a musical composition or a joke) or a physical object (such as an invention, a literary work or a painting).”

- **DII (descriptions for images in isolation)**: Traditional storytelling software
- **SIS (stories for images in sequence)**: new approach towards storytelling, including
  - Based on SIND - Sequential Image Narrative Dataset: 81,743 unique photos in 20,211 sequences, aligned to both descriptive (caption) and story language.
  - [Margaret Mitchell / Microsoft, 04/2016, together with colleagues from Facebook]

<table>
<thead>
<tr>
<th>DII</th>
<th>SIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A group of people that are sitting next to each other.</td>
<td>Having a good time bonding and talking.</td>
</tr>
<tr>
<td>Adult male wearing sunglasses lying down on black pavement.</td>
<td>[M] got exhausted by the heat.</td>
</tr>
<tr>
<td>The sun is setting over the ocean and mountains.</td>
<td>Sky illuminated with a brilliance of gold and orange hues.</td>
</tr>
</tbody>
</table>

**Visual-Storytelling by Microsoft** based on deep neural networks (convolutional neural networks)
“Creativity is a phenomenon whereby something new ... is formed. The created item may be intangible (such as an idea, a scientific theory, a musical composition or a joke) or a physical object (such as an invention, a literary work or a painting).”

[adapted from Wikipedia, last visited 5/3/2016]

“Do Androids Dream of Electric Sheep?”
(science fiction novel by American writer Philip K. Dick, published in 1968)

Computational creativity (artificial creativity) ... is a multidisciplinary endeavour that is located at the intersection of the fields of artificial intelligence, cognitive psychology, philosophy, and the arts.

[adapted from Wikipedia, last visited 5/3/2016]

„Can machines be creative?“ by Iamus, a computer cluster composing classical music by genetic algorithms, concert for Turings 100th birthday

[youtube]

Van Gogh’s Starry Night interpreted by Google DeepDream based on deep neural networks
Summary
... in four steps!

4.0: Revolution of a distributed artificial intelligence

- IT driven
- characterized by “everything/body is connected to everything/body anywhere anytime”.
- rediscovery of cybernetics

Innovation – a question of culture

- 4.0 is a IT-driven.
- Its “networked” character brings technological and social innovations closer together than ever.
- The innovators of today differ from the ones before.
- Globalization has its additional effects on speed and plurality...

4th Industrial Revolution

We are right in the middle of a 4th Industrial Revolution.

4.0 is an era of highly interdisciplinary cooperations

- applications are smart cars, smart cities, new work models in production etc.
- Solutions for decentralized systems are highly influenced by biological models.
- Artificial intelligence profits from computer linguistics, psychology, neuro sciences...

The rise of cognitive computing

- Addressing problems of “human-like” complexity
- Copying human thought processes
- Intuitive intelligent interaction with humans...
Thank you!

Univ.-Prof. Dr. rer. nat. Sabina Jeschke
Head of Institute Cluster IMA/ZLW & IfU
phone: +49 241-80-91110
sabina.jeschke@ima-zlw-ifu.rwth-aachen.de

Co-authored by:

Prof. Dr.-Ing. Tobias Meisen
Institute Cluster IMA/ZLW & IfU
tobias.meisen@ima-zlw-ifu.rwth-aachen.de

Dipl.-Inform. Christian Kohlschein
Institute Cluster IMA/ZLW & IfU
christian.kohlschein@ima-zlw-ifu.rwth-aachen.de
<table>
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<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1968</td>
<td>Born in Kungälv/Schweden</td>
</tr>
<tr>
<td>1994</td>
<td>NASA Ames Research Center, Moffett Field, CA/USA</td>
</tr>
<tr>
<td>10/1994</td>
<td>Fellowship „Studienstiftung des Deutschen Volkes“</td>
</tr>
<tr>
<td>1997</td>
<td>Diploma Physics</td>
</tr>
<tr>
<td>1997 – 2000</td>
<td>Research Fellow, TU Berlin, Institute for Mathematics</td>
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<tr>
<td>2000 – 2001</td>
<td>Lecturer, Georgia Institute of Technology, GA/USA</td>
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<td>2001 – 2004</td>
<td>Project leadership, TU Berlin, Institute for Mathematics</td>
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<tr>
<td>04/2004</td>
<td>Ph.D. (Dr. rer. nat.), TU Berlin, in the field of Computer Sciences</td>
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<tr>
<td>2004</td>
<td>Set-up and leadership of the Multimedia-Center at the TU Berlin</td>
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<tr>
<td>2005 – 2007</td>
<td>Juniorprofessor „New Media in Mathematics &amp; Sciences“ &amp; Director of the Multimedia-center MuLF, TU Berlin</td>
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<tr>
<td>2007 – 2009</td>
<td>Univ.-Professor, Institute for IT Service Technologies (IITS) &amp; Director of the Computer Center (RUS), Department of Electrical Engineering, University of Stuttgart</td>
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<td>since 06/2009</td>
<td>Univ.-Professor, Head of the Institute Cluster IMA/ZLW &amp; IfU, Department of Mechanical Engineering, RWTH Aachen University</td>
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<tr>
<td>since 10/2011</td>
<td>Vice Dean of the Department of Mechanical Engineering, RWTH Aachen University</td>
</tr>
<tr>
<td>since 03/2012</td>
<td>Chairwoman VDI Aachen</td>
</tr>
<tr>
<td>since 05/2015</td>
<td>Supervisory Board of Körber AG, Hamburg</td>
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