Robotics in Industry 4.0

History, Presence and Future of Robotics in Car Industry

Simulierte oder gelebte Kollaboration: Bewegung und Entgrenzung in der Industrie 4.0

Lüneburg, February 2nd, 2016

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IMA/ZLW & IfU
Faculty of Mechanical Engineering
RWTH Aachen University

Outline

Breakthroughs – A new era of artificial intelligence

Communication technology
bandwidth and computational power

Embedded systems
miniaturization

Watson
2011

Semantic technologies
information integration

Google Car
2012

Breakthroughs – Everybody and everything is networked

Communication technology
bandwidth and computational power

Embedded systems
miniaturization

Semantic technologies
information integration

Car2Infra-structure

Swarm Robotics

Team Robotics

Smart Factory

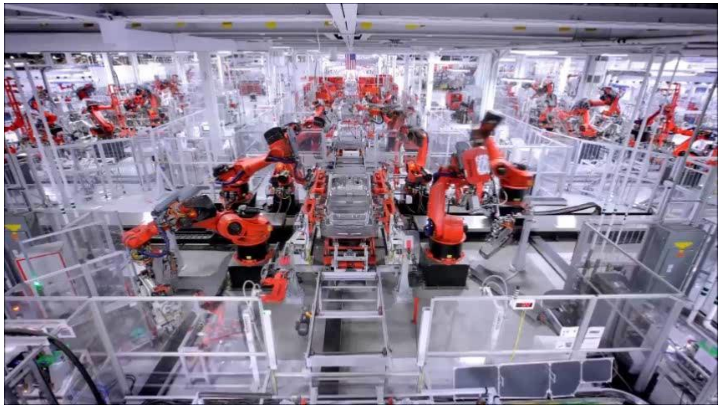
Smart Grid

… entering all spheres: from public to privat…

Household

Industry

[7]



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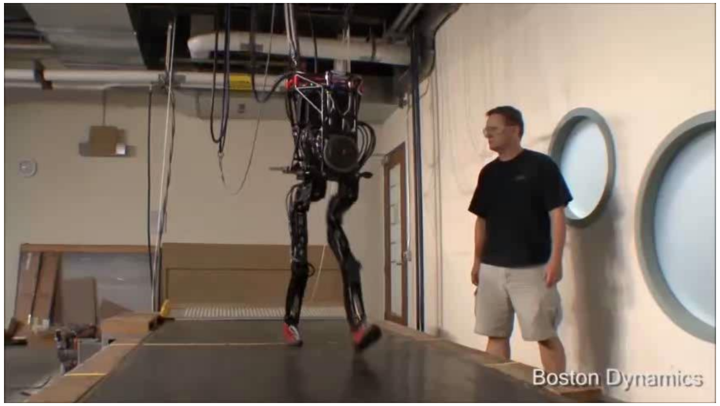

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[10]

Military

Medicine

Rise of autonomous intelligent systems in all areas

Breakthrough – the Google Driverless Car 2012

© Google 2012

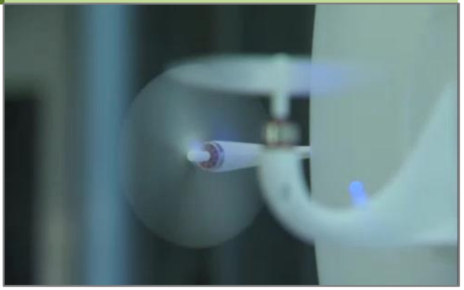
Management of uncertainty:
resulting from
- differences between procedures of humens vs technical systems
- changing environment and
- highly time-dependent processes

Drones:
unmanned aerial vehicles

© Maternet 2012

Mobile robotics in production & logistics:
from "stupid" stationary to intelligent mobile systems

Swarm Intelligence:
not one but many….



© Festo

… leading to robotics for logistics tasks

→ Flexible concept for logistics…

Perceive: Position (GPS), speed, weather, task

Think: Attitude and flight characteristics, safety

Act: Set motor speed, drop packet

Future of package delivery

[12]

DHL

[13]

Amazon

→ Resulting in…

Internet access down from the skies

New delivery services

First aid support

… but also, new ways of crime

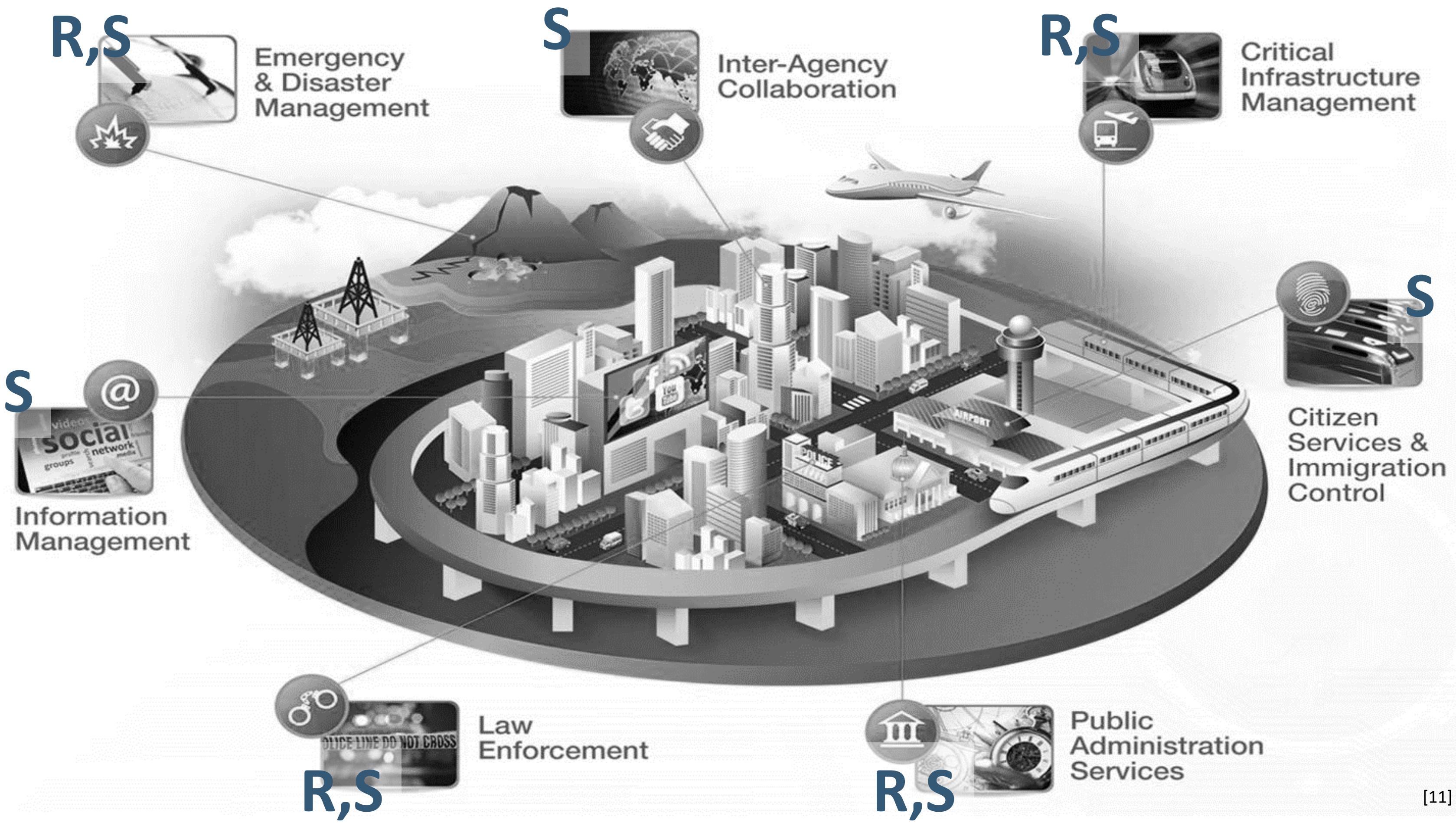
Primary care (Emergency)

[10]

TU Delft

The vision of a smart city…

! Smart Cities: A place where Services and Robotics meet



… leading to robotics in garden maintenance and cleaning

New ways to handle cleaning and garbage collection…

! Street-cleaning

[14]

! Park-cleaning


[15]

! Garbage collection


[16]

… as well as garden maintenance

Plant care like watering, manuring, cutting, …

… and sowing, planting, …


[17]

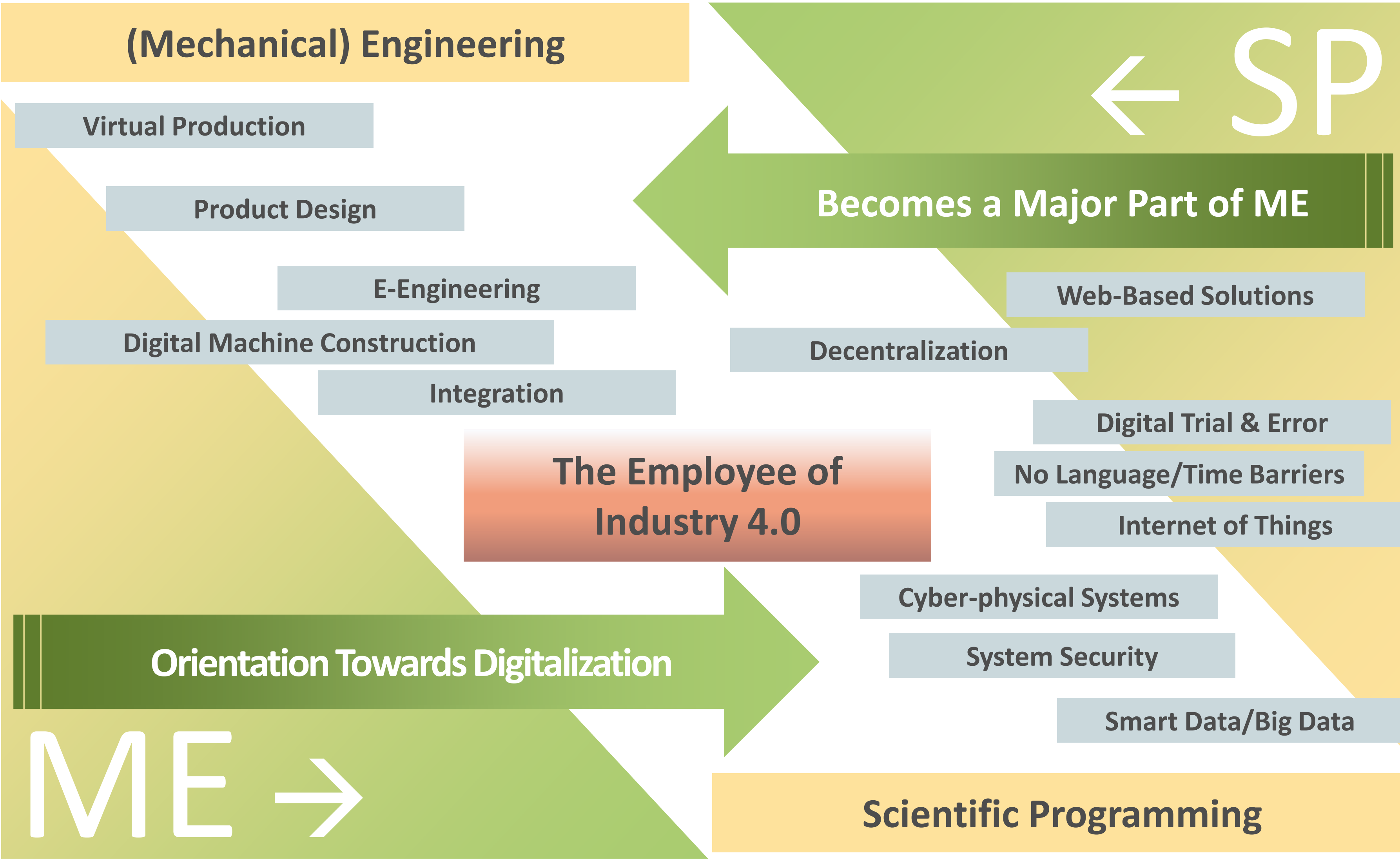
Robots in general – some facts and numbers

! Figures are climbing up as investments and markets grow [The Robot Report 2015]

- → **Dyson sponsored** a **robotics centre** at Imperial College London for **£5 million**
- → **$125 million investments** within the European Commissions **Horizon 2020**
- → **$500 million investments** in the **next 5 years** trying to catch up with **China and Japan**
- → **Google** spent **$643 million** in a **single acquisition buying Deepmind**
- → **Prime Minister estimates** a national **$22 billion market** in **2020**
- → Overtook Japan to become the **biggest robot market** of the **world**, sold **38,000 robots in 2013**

! Summary: Robots are already used in multiple scenarios and use cases. The technology is available and high investments are already in place ➔ the race has already begun.

“Informatics is the new latin”…



Leading to: Interdisciplinary science and education

Natural language communication

Virtual reality

Augmented reality

Human-Maschine Interaction

Antropo-morphism

Uncanny valley

Social Robotics

Automated driving

Lightweight robots

Autonomous systems

Autonomous flying

New fields of work

Smart Logistics

Cloud logistics

Swarm robotics

Car2X

Autonomouos intralogistics

… ? …

Business Computing

Risc analysis

Data Analysis

Outline

The vendor change around „cars“

For other dimensions of “take overs”, see keynote “Innovation 4.0”: http://www.ima-zlw-ifu.rwth-aachen.de/keynotes/LTLS_15Okt2015.pdf

Characteristics of Industrial Revolutions: The vendor change

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

SONY

Ford 021C concept car 2012, designed by Newson now at Apple (1999)

Apple Inc.

Google: First autonomic car with street license, 2012

Google

Car specialists? – No.

- **Connectivity & data specialists.**
- **Energy & sensor specialists.**

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

Around 1750	Around 1900	Around 1970	Today
1st Industrial Revolution Mechanical production systematically using the power of water and steam	**Power Revolution** Centralized electric power infrastructure; mass production by division of labor	**Digital Revolution** Digital computing and communication technology, enhancing systems’ intelligence	**Information Revolution** Everybody and everything is networked – networked information as a “huge brain”

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

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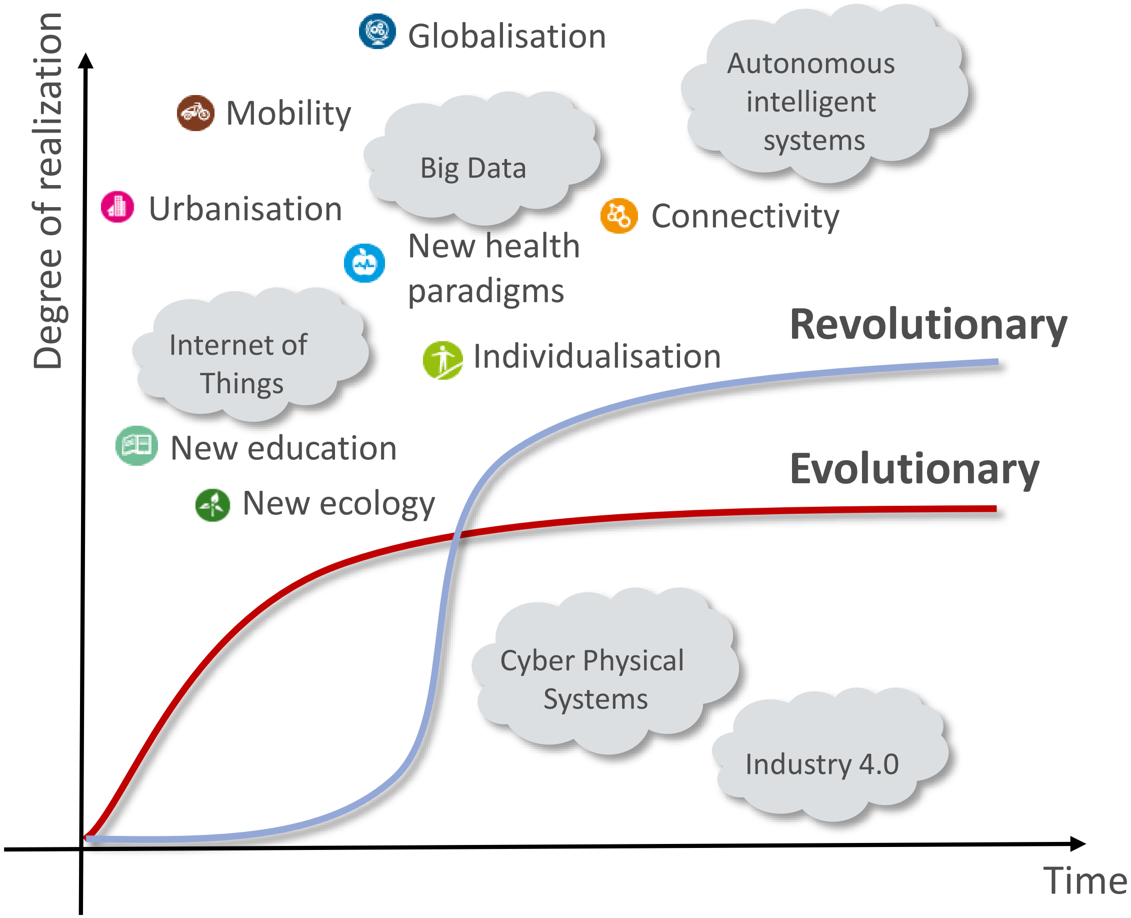
The two ways of innovation



BusinessDictionary.com
Over 20,000 Terms. Clear. Concise. Comprehensive.

"Innovations are divided into **two categories**:

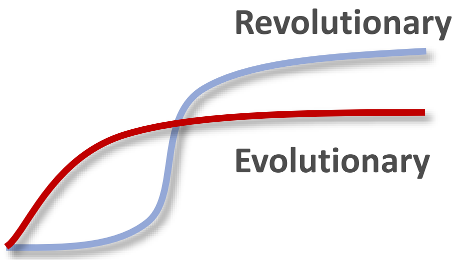
- **Evolutionary innovations** (continuous or dynamic evolutionary innovation) that are brought about by many incremental advances in technology or processes and
- **Revolutionary innovations** (also called discontinuous innovations) which are often disruptive and new."

!

IMPORTANT:

- In times of Industrial Revolutions, the revolutionary innovations dominate.
- In the times between, the evolutionary innovations dominate.

The innovators' dilemma



Evolutionary innovations:

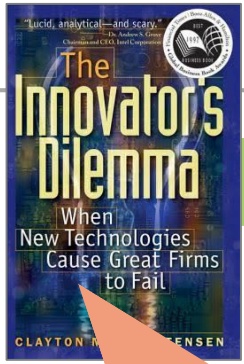
- Improvement and optimization of an already existing product or process
- Changes ‚locally'

- **Mainly carried out by established players**

Revolutionary innovations:

- Something „really new"
- Characterized by categorial changes and with strong consequences for the society, ‚globally'

- **Mainly carried out by market newcomers**



By C. M. Christensen, 1997
new edition 2015

- 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' sugestions 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**

"Information Revolution" – implications for the car industry

Towards eMobility and eMobility components

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

For the automobile industry, that means:

The production is changing
– AND –
the product is changing !

In February 2015, Audi installed collaborative robots – "Cobots" in Ingolstadt, working "hand-in-hand" with humans

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

„local" to „global"

„local" to „global"

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"Information Revolution" – implications for the car industry

Towards eMobility and eMobility components

Vision by pgottschalk

Robots Producing Robots!!

Concept car Mercedes F105

„local" to „global"

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Robots everywhere: Changes in the product …

USA in the 1950s: "Electronic Highway"

- Project by GM and RCA
- Technology: **inductive cable in the road**

California 1992: "PATH" – incl. cooperative driving

- Lidar/radar sensors, automated driving, platooning, real time communication
- **Similar Projects:** in Europe and Asia

Japan 1977: "IVS" – vision based

- **binocular** machine vision, various control algorithms, automated steering, **30 km/h**
- **Similar Projects** in Germany, France and USA

Towards enhanced flexibility and intelligence

Google's prototype of its self-driving car (05/2014)

- built-from-scratch, no steering-wheel or pedals
- test fleet of about 100 cars
- Technology: AI, fully automated driving, vision analysis, big data, …

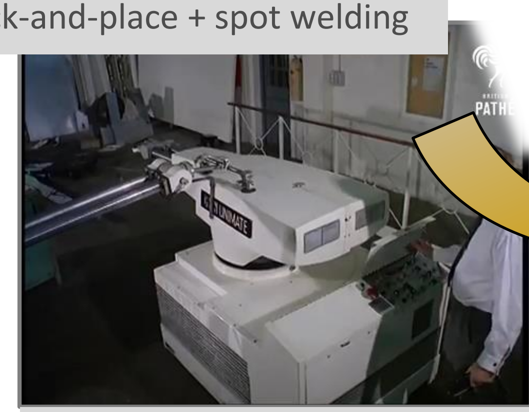
Bertha Benz Drive (09/2013)

- S-Class: autonomous drive on historical route (Mannheim – Pforzheim)
- Sensors: mainly „standard" sensor technology today embedded into cars anyway

Robots everywhere: … and in the production !

GM uses the **first robot in automotive industry** (1961)

- "UNIMATE", by Unimation
- pick-and-place + spot welding



Industrial One-Arm Bandit (1968)

- based on UNIMATE
- **first programmable industrial robot**
- local intelligence (3rd ind. revolution)

Towards enhanced flexibility and intelligence

First 6 axis robot (1973)

- FAMULUS, by KUKA
- Enhancing the movements of robots

Super motion control by ABB Robotics (2009)

- enhanced real-time capability

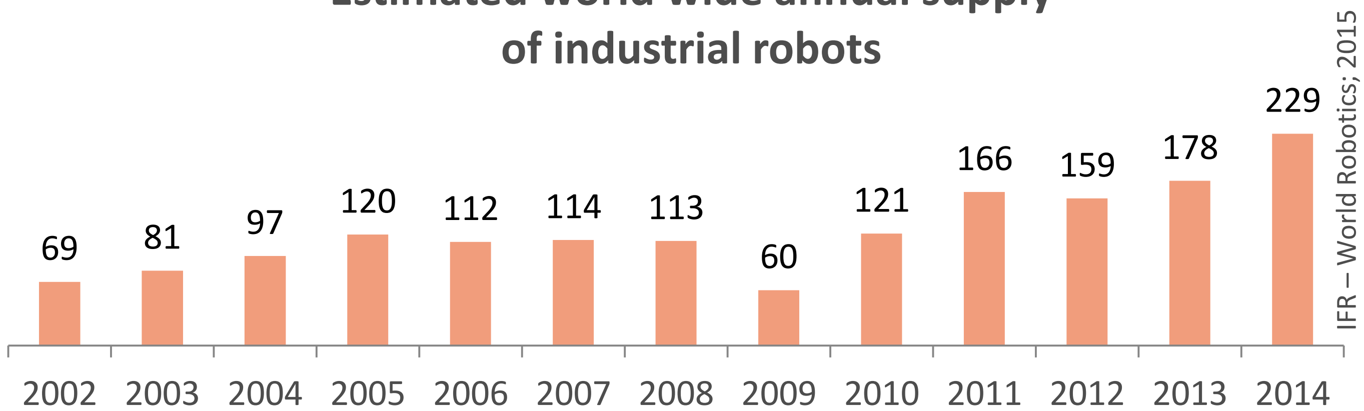
Components from Schuler pressroom (at BWM 2009)

- Including Xbar robots
- Optimization by mimicking biological-inspired movements

Robotics in automotive industry by the numbers and subsection

- 1980: approx. 1.200 industrial robots in Germany.
- 2000: approx. 109.000 (about 750.000 world-wide)
- > 50% in automotive industry

Estimated world wide annual supply of industrial robots



!
- Today, no other industry applies more robots
- Robotics are a part of nearly all areas of automotive industry

Press Shop > 90 %

Body Shop > 90 %

Paint Shop > 90 %

Assembly ≈ 20 %

Evolutionary vs. revolutionary developments

Towards eMobility and eMobility components

2 central questions concerning the „roboterization“ of the car production

What are the next steps in the

EVOLUTIONARY

development

of car manufacturing?

What are the next steps in the

REVOLUTIONARY

development

of car manufacturing?

Outline

I. **Introduction – Robots in the Connected World**
- The fourth industrial revolution
- The rise of robotics
- … in all areas

II. **Robots in the Car Industry**
- The changes in the car industry: The product…
- … and the production!

III. **The Evolutionary Change: Automotive Production Tomorrow**
- Decentralized steering paradigms
- Changes in intralogistic flows
- Coupling to Logistics 4.0
- Hybrid teams: new human-robot cooperation
- 3D-Printing
- Robotics for eCars

IV. **The Revolutionary Change: Future Perspectives and Challenges**
- Robots in maintenance and repair
- The car is a computer (!?)
- Towards organic and cognitive computing
- From embodiment … to humanoids

V. **Summary**

With decentralized models towards lot size 1

Lot Size 1 in 4.0

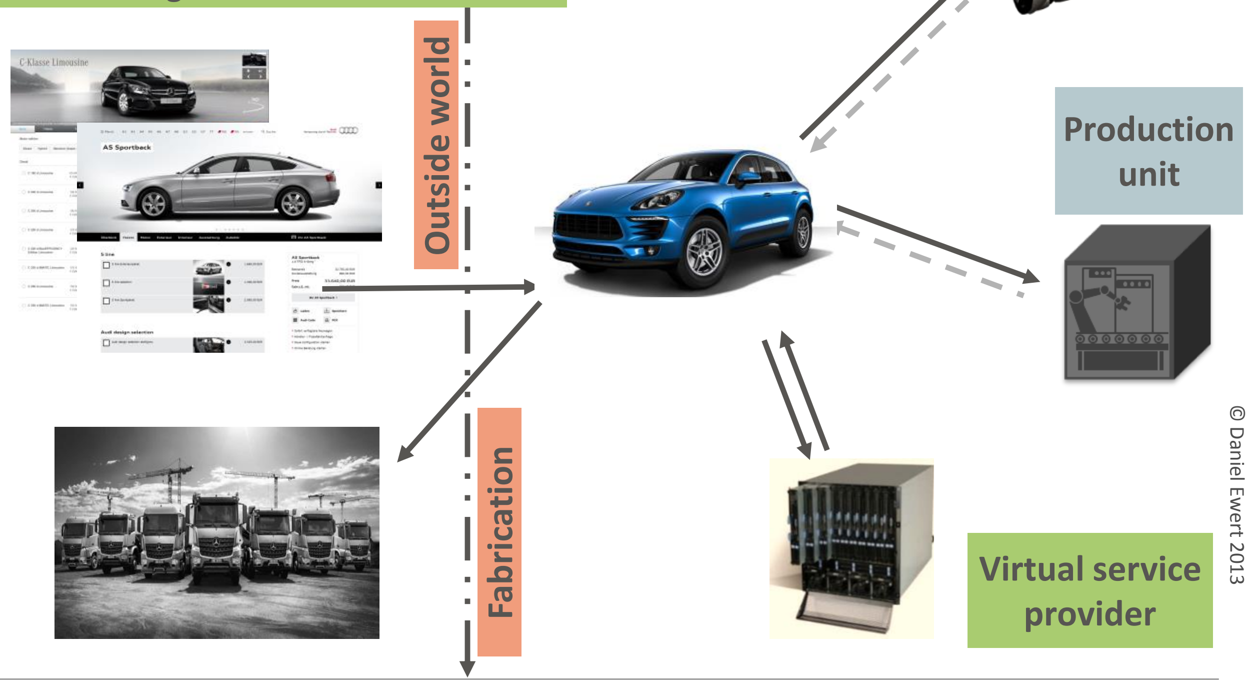
Organization forms on demand – individualized by client – initialized by product

- Heterogeneous player modeled as multi agent concept
- Models from biology and social sciences
- Based on autopoiesis & embodiment theory

!

Product agitates as "super-agent":

- Plans production and transportation steps
- Requests services from agents
- Negotiates with other products for agent-resources



Horizontal coupling - manufacturing and logistics

Logistics 4.0

Organization forms on demand – individualized by client – initialized by product

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Product agitates as “super-agent”:

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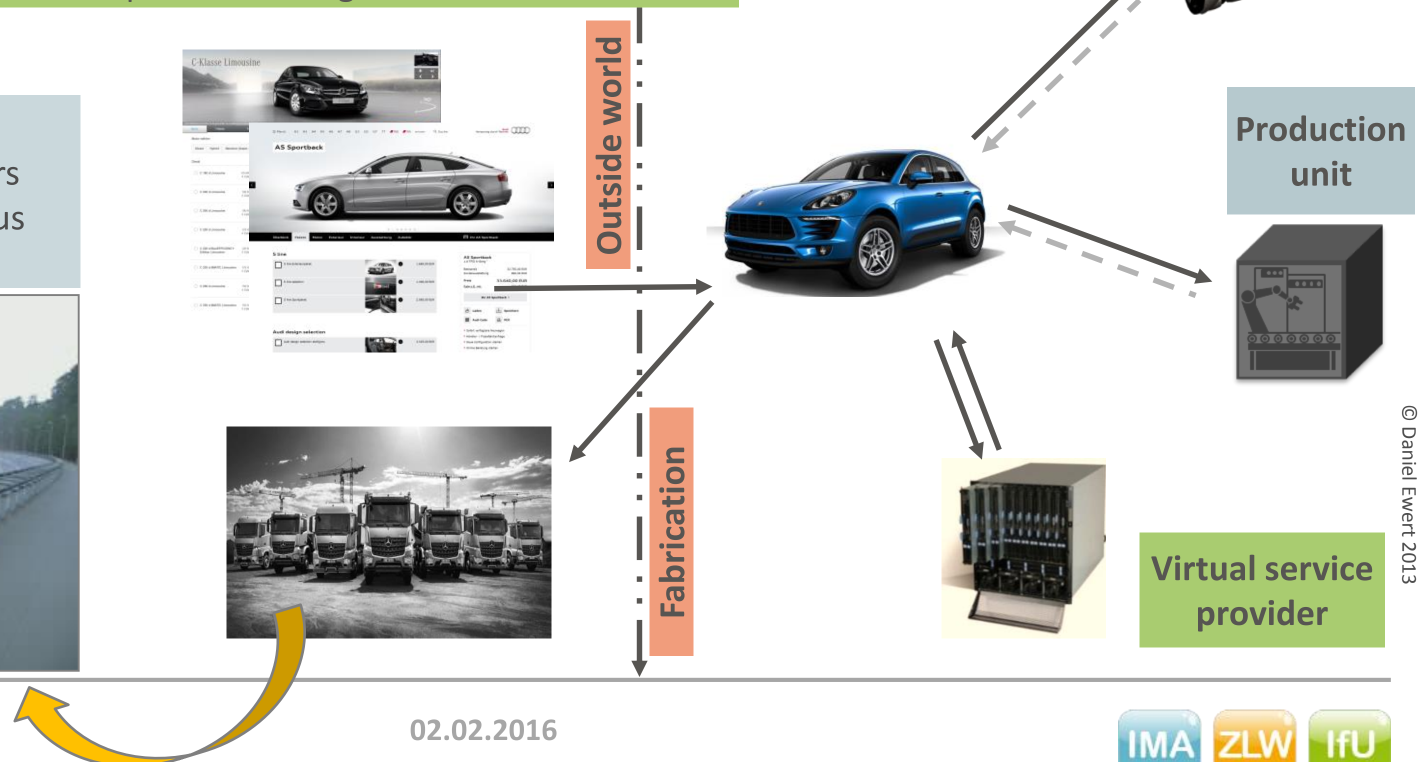
- Konvoi 2005-2009, RWTH with partners
- (partly) autonomous driving via convoys



Changes already „under construction“

Intralogistics goes mobile: The Festo Logistics League

Intralogistics 4.0

Mobile transportation robots from flexible routing

KBSG Knowledge-Based Systems Group · FH AACHEN UNIVERSITY OF APPLIED SCIENCES · IMA ZLW IfU

!

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

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

http://www.carologistics.org/

Towards human-robot cooperation: hybrid teams

Audis collaborative robots in Ingolstadt, the “Cobots” pick up components and pass them to workers (02/2015)

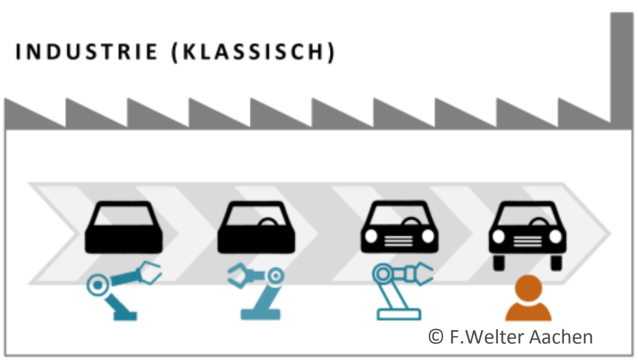
New “body concepts” for robots
- New types of “sensible” robots, mainly “lightweight”

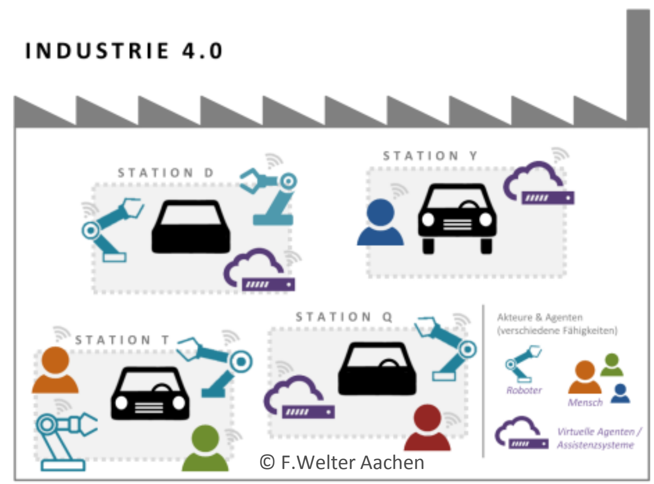
Real-time capability:
- New fast sensors allows avoiding accidents in close cooperation

New intelligence models:
- New AI for “context understanding”

PhD Ying Wang, RRWTH, IMA/ZLW & IfU, 2016

→ Towards hybrid teams and in-the-box production

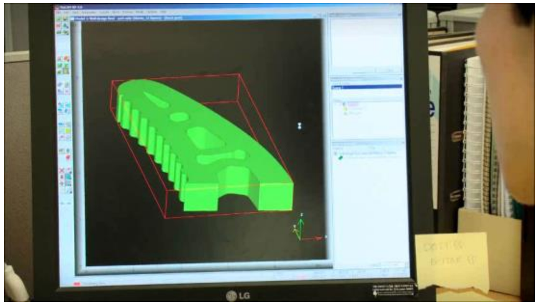


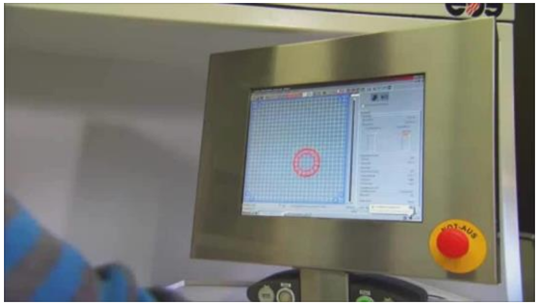


New materials and material handling

- Starting from rapid prototyping, additive manufacturing is used in more an more areas
- From “maker movement” to professional products

! **3D Printing – The Path to Individualized Mass Production?**





! **Multiple materials:** photopolymers, thermoplastic powders, rubbers, ceramics, cements, metal alloys, noble metals, paper, …

Already now, people consider „…a 3D printer to be a type of industrial robot.“ (Wikipedia)

Combining

3D print

and

Robotics

may lead to

totally new ways of

production technology…

Outline

Robots in maintenance and repair

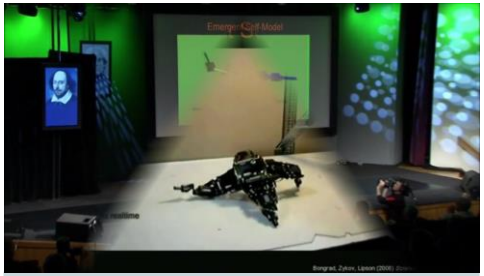
→ **Spontaneous reaction: "…well, repair is a very complicated part of (re-)fabrication since all cases are 'different' – certainly, repair will be a very late phase of robot integration…"**

TRUE? – 4 somewhat "crazy" thoughts…

1) Tesla's Robotic Metal Snake Charger (youtube, 2015): not exactly "repair" but "maintenance". Concept could be adapted to other tasks as oil change etc.

2) In the diagnosis – before the repair – , computers (perceived as robot w/o body) already have an important role (pic.: default memory, Bosch)

3) In medicine, all cases are "different" due to the individuality of humans – however, robots have entered the medical field (picture: Da Vinci robot)



4) Finally, research has already developed self-repairing robots – if cars are going to be robots, the same concept could be used (youtube: Bongards' robot 2006)

New ways for internal construction of a car

If cars are to become „computers on wheels“ – then the question is:

How do we produce computers in the future… ??

→

- **In 2011**, Foxconn announced to install an army of one million robots in the coming 3 years – mainly for the fabrication of mobile computers as e.g. iPhone 6.
  - the reason: “costs”, costs of labor are raising even in China, and robots are cheaper anyway
- **In 2014,** it became clear that high development costs and rapid changes in technology have slowed down progress.
- However, since **Sommer 2015** it is obvious that Foxconn finally comes very close to its original goals. Human workforce has already been reduced to one half.

Robotized automation, FRIDA/ABB: an approach to the „Foxbot“?

„Foxbots“ in Summer 2015 (youtube)

Vehicle concepts change dramatically…

Design 4.0

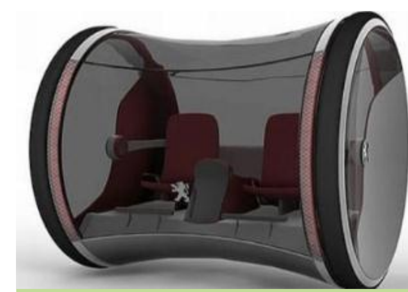
→ New vehicle concepts

Autonomous and **cooperative driving** lead to **new vehicle concepts** and **new tasks** for the driver

Mercedes F 015

Rinspeed XchangeE

Zoox Boz

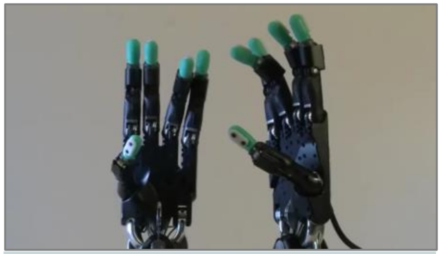


Peugeot „Ozone“

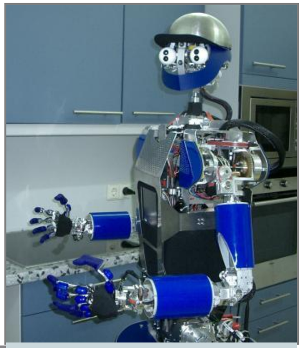
From embodiment … to humanoids

Embodiment theory I:
„intelligence needs a body"

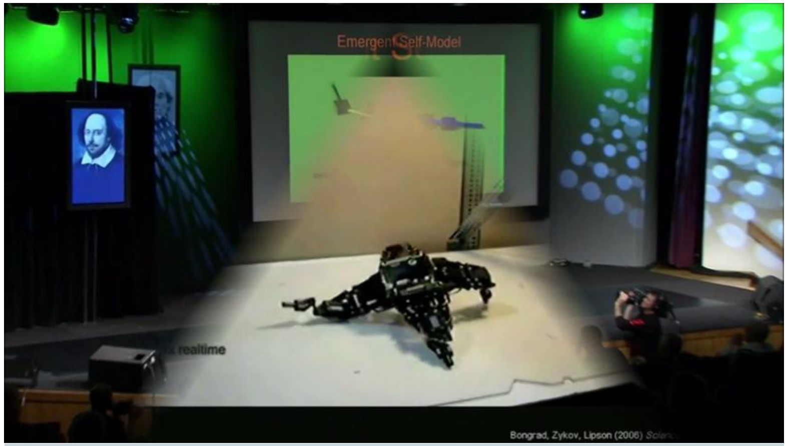
The existence of a body (incl. sensors and actuators) are basic prerequisites to build experience and finally the development of intelligence.



Shadow Dexterous Hand

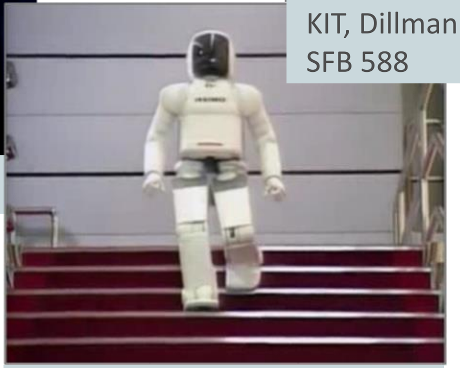


KIT, Dillmann, SFB 588



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

Robonaut 2- NASA



Asimo Honda

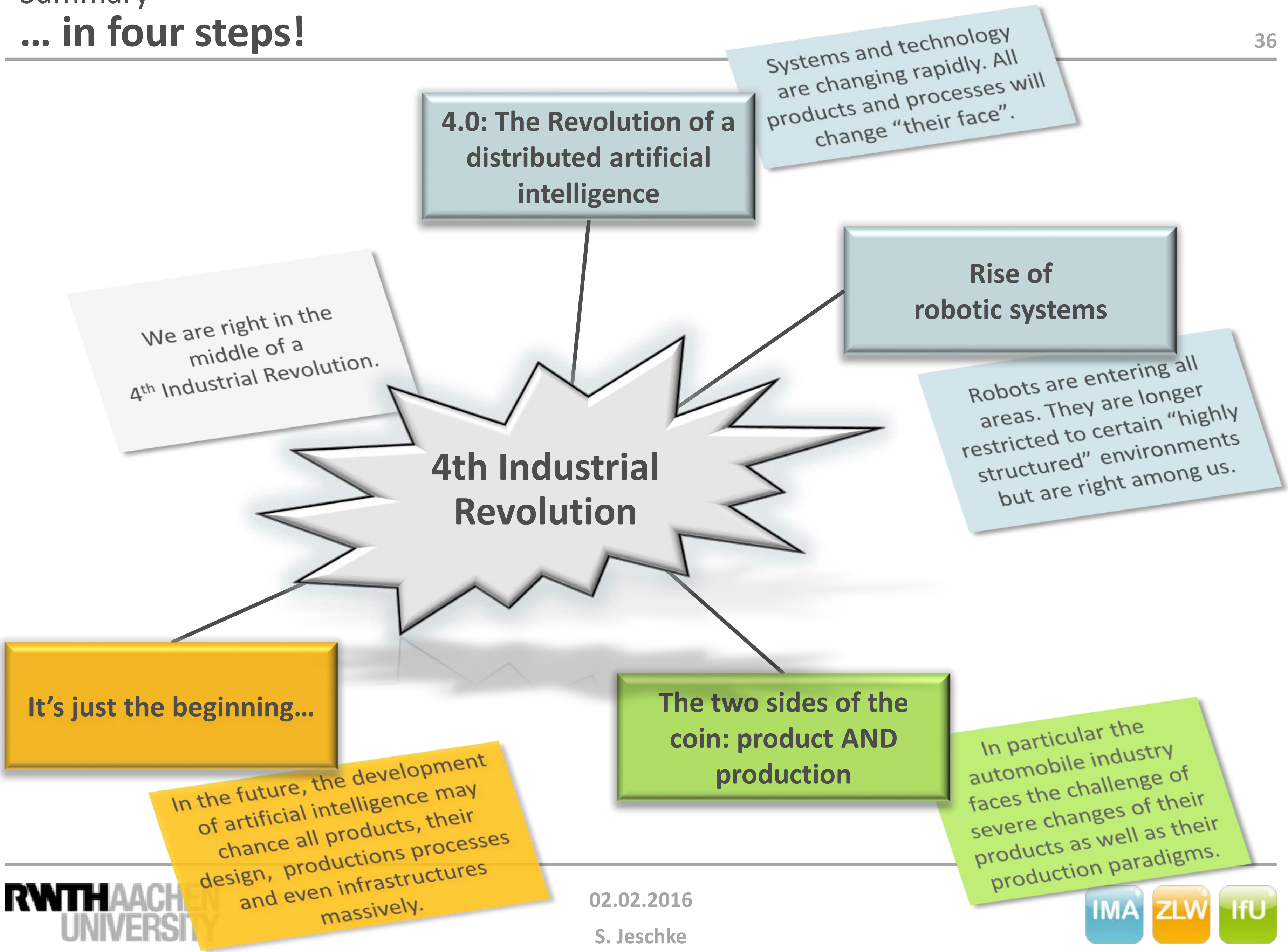
Embodiment theory II:
„different bodies = different intelligences"

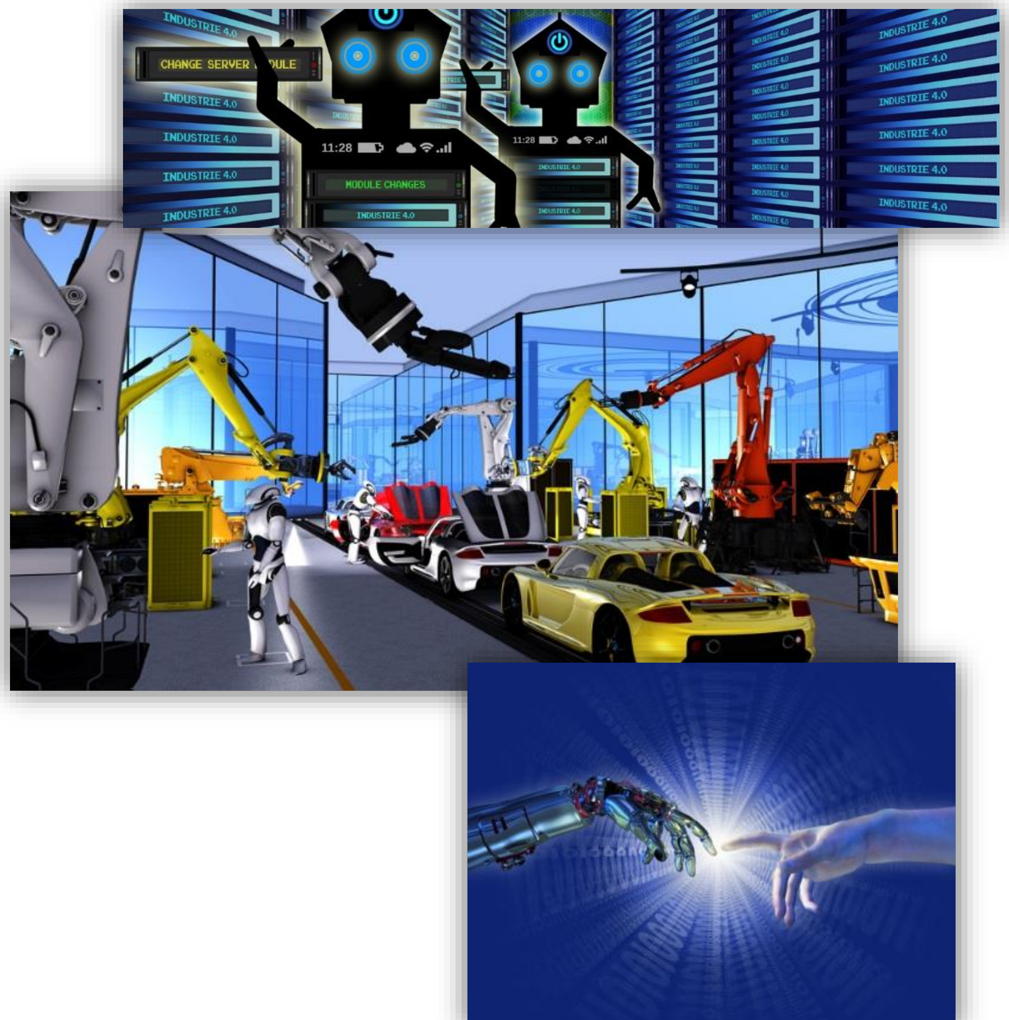
… leading to humanoids / humanoid components

Thus, the robotics in manufacturers will change accordingly.

Outline

… in four steps!





Thank you!

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Prof. Dr. rer. nat. Sabina Jeschke

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1991 – 1997	Studies of **Physics, Mathematics, Computer Sciences,** TU **Berlin**
1994	**NASA** Ames Research Center, Moffett Field, **CA/USA**
10/1994	Fellowship „Studienstiftung des Deutschen Volkes“
1997	Diploma Physics
1997 – 2000	**Research Fellow** , TU Berlin, Institute of **Mathematics**
2000 – 2001	**Lecturer**, Georgia Institute of Technology, **GA/USA**
2001 – 2004	**Project leadership**, TU Berlin, Institute for Mathematics
04/2004	**Ph.D.** (Dr. rer. nat.), TU Berlin, in the field of **Computer Sciences**
2004	Set-up and leadership of the Multimedia-Center at the TU Berlin
2005 – 2007	**Juniorprofessor** „New Media in Mathematics & Sciences“ & Director of the **Multimedia**-center MuLF, TU Berlin
2007 – 2009	**Univ.-Professor**, Institute for IT Service Technologies (IITS) & Director of the Computer Center (RUS), Department of **Electrical Engineering**, University of **Stuttgart**
since 06/2009	**Univ.-Professor**, Head of the Institute Cluster IMA/ZLW & IfU, Department of **Mechanical Engineering**, RWTH **Aachen** University
since 10/2011	**Vice Dean** of the Department of **Mechanical Engineering**, RWTH **Aachen** University
since 03/2012	**Chairwoman VDI Aachen**
since 05/2015	**Supervisory Board of Körber AG**, Hamburg