Robotics in Automobile Industry
History, Presence and Future

Fachkonferenz
Roboter in der Automobilindustrie
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Outline

I. Introduction – The connected world
   - The fourth industrial revolution
   - ... and its implications to the car / mobility industry
   - The changes in the car industry: The product...
   - ... and the production!

II. 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

III. 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

IV. Summary
The connected world

Breakthroughs – A new era of artificial intelligence

Communication technology
bandwidth and computational power

Semantic technologies
information integration

Embedded systems
miniaturization

Google Car
2012

Watson
2011
The connected world
Breakthroughs – Everybody and everything is networked

Communication technology
bandwidth and computational power

Semantic technologies
information integration

Embedded systems
miniaturization

- Car2Infra-structure
- Team Robotics
- Smart Factory

- Swarm Robotics
- Smart Grid
The connected world

The vendor change around „cars“

Characteristics of Industrial Revolutions: The vendor change

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”

For other dimensions of “take overs”, see keynote “Innovation 4.0”:

Google: First autonomic car with street license, 2012

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)

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

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

Google: First autonomic car with street license, 2012

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

Around 1970

Google

Apple Inc.

Tesla

Sony

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The connected world
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The connected world

“Information Revolution” – implications for the car industry

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!

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The connected world
“Information Revolution” – implications for the car industry

Towards eMobility and eMobility components

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Robots Producing Robots!!

Vision by pgottschalk
Concept car Mercedes F105

Around 1750
Around 1900
Around 1970
Today

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The trend towards robotics
Robots everywhere: Changes in the **product** ...

USA in the 1950s: “Electronic Highway”
- Project by GM and RCA
- Technology: inductive cable in the road

Japan 1977: “IVS” – vision based
- **binocular** machine vision, various control algorithms, automated steering, **30 km/h**
- Similar Projects in Germany, France and USA

California 1992: “PATH” – incl. cooperative driving
- Lidar/radar sensors, automated driving, platooning, real time communication
- Similar Projects: in Europe and Asia

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, ...

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Towards enhanced flexibility and intelligence

Bertha Benz Drive (09/2013)
- S-Class: autonomous drive on historical route (Mannheim – Pforzheim)
- Sensors: mainly „standard“ sensor technology today embedded into cars anyway

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The trend towards robotics

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)

First 6 axis robot (1973)
- FAMULUS, by KUKA
- Enhancing the movements of robots

Towards enhanced flexibility and intelligence

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
The trend towards robotics

Robotics in automotive industry by the numbers and subsection

- 1980: approx. 1,200 industrial robots in Germany.
- 2000: approx. 109,000 (about 750,000 worldwide)
- > 50% in automotive industry

Estimated world wide annual supply of industrial robots

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![IFR – World Robotics, 2015](image)

- 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 %

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How automotive production is going to change

Evolutionary vs. revolutionary developments

Towards eMobility and eMobility components

2 central questions concerning the "robotization" 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?

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IV. Summary
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

Changes already „under construction“
With decentralized models towards lot size 1
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Konvoi 2005-2009, RWTH with partners
- (partly) autonomous driving via convoys

Horizontal coupling - manufacturing and logistics

Changes already „under construction“
Changes already „under construction“

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

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

- 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”

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

Towards hybrid teams and in-the-box production

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

INDUSTRIE 4.0

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Changes already „under construction“

New materials and material handling

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

3D Printing – The Path to Individualized Mass Production?

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...

Multiple materials: photopolymers, thermoplastic powders, rubbers, ceramics, cements, metal alloys, noble metals, paper, ...
Changes already „under construction“

Automation for the power train of eCars

Production for eCars: Challenge power train

Mercedes-Benz B Class Electric Drive: “Tesla inside”. Next version w/o Tesla, own modules.

Project Epromo – mass production technology for eCars (IAO Fraunhofer, team technik, ...): “Today, profitable mass production is still impossible as the automated manufacturing of power drive components for electronic vehicles is still in its infancy”

2nd picture: B class, Rastatt, both models (gasoline engine vs. electric drive) on the same conveyor line:

- the challenge is not the car overall, it is mainly given by the (new) power drive components
- new competencies required from the employees in production, but the automation technology is still the same
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What has to be expected?
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? – 5 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)

5) 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)
Changes already „under construction“

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)
What has to be expected?

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.

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

**Embodiment theory II:** „different bodies = different intelligences“

... leading to humanoids / humanoid components

**Thus, the robotics in manufacturers will change accordingly.**

Robonaut 2 - NASA

Kit, Dillmann, SFB 588

Asimo Honda
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Summary
... in four steps!

4.0: The Revolution of a distributed artificial intelligence

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

New materials and new material processing
Additive and generative manufacturing is still in its early stages. In the future it will change repair and maintenance as well as in production itself.

4th Industrial Revolution

The two sides of the coin: product AND production
The automobile industry faces the challenge of severe changes of their products as well as their production paradigms.

The vendor change: New players enter the market
The innovators of today differ from the ones before. Globalization has its additional effects on speed and plurality...

Systems and technology are changing rapidly. All products and processes will change “their face”. Robotic system are going to influence all areas.
Thank you!

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since 03/2012 Chairwoman VDI Aachen
since 05/2015 Supervisory Board of Körber AG, Hamburg
New ways of steering and control mechanisms
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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What has to be expected?

**Vehicle concepts change dramatically...**

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“**
What has to be expected?

Autonomous multimodal mobility structure

- Concept of connected autonomous vehicles:
  - not limited to road traffic, but will instead effect all modes of transport
  - Goal: accident, emission and congestion free transport system
  - offers potential contributions to meet challenges like urbanization, global warming, demographic change and individualization.

→

Thus, the demands towards the manufacturers will change accordingly.
What has to be expected?
From organic ... to cognitive computing

Organic computing:
Following social systems and biological models

Cognitive computing:
The simulation of human thought processes

Division of labor

Hardware
- Macro-scale Automation
- Micro-scale Multi-Core

Software
- Service oriented
- Agent-based

SOFTWARE – deep learning (e.g. Watson)

“Cognitive computing (CC) makes a new class of problems computable. It addresses complex situations that are characterized by ambiguity and uncertainty - 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”.”

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