"Society 4.0 – Digital Age and Artificial Intelligence are driving the Change of Societies and Organizations“

10th „Daimler Sustainability Dialogue“
Stuttgart, November 8th, 2017

Univ.-Prof. Dr.-Ing. Klaus Henning

Senior Advisor Cybernetics Lab IMA/ZLW & IfU
RWTH Aachen University, Aachen

Senior Partner P3 OSTO GmbH, Köln

Chairman Advisory Board Xenium A.G., München

Outline

Outline

I. **The Age of Artificial Intelligence**

- The Rise of Artificial Intelligence and its Relation to 4.0
  - Intelligent Self-learning Systems

II. **Society 4.0 and Work 4.0**

- Changes of the Occupational Areas
- Organizational Changes and Platform Economies
- Artificial Intelligence changes Society

III. **Summary and Outlook**

Breakthroughs

Communication technology
bandwidth and computational power

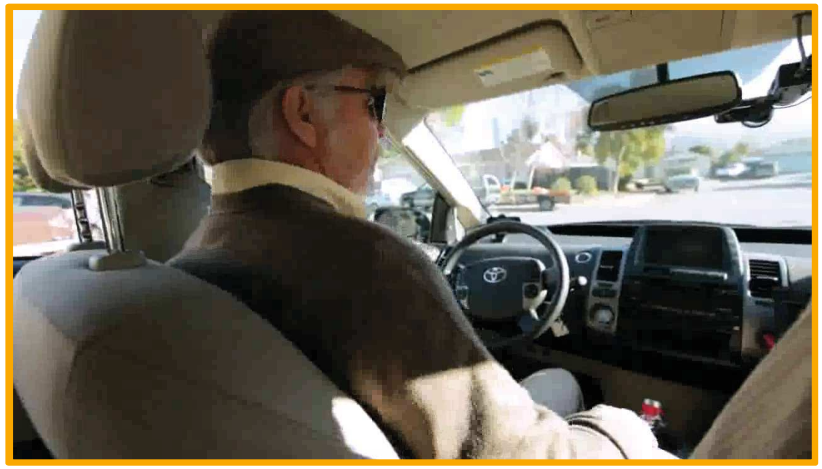
Embedded systems
miniaturization

Semantic technologies
information integration

Artificial intelligence
behavior and decision support

Watson 2011

Google Car 2012



→ **Systems of "human-like" complexity**

1st dimension: complexity level

Breakthroughs

Communication technology
bandwidth and computational power

Embedded systems
miniaturization

Semantic technologies
information integration

Artificial intelligence
behavior and decision support

2nd dimension: network level

Swarm Robotics

Team Robotics

Car2Infra-structure

Smart Grid

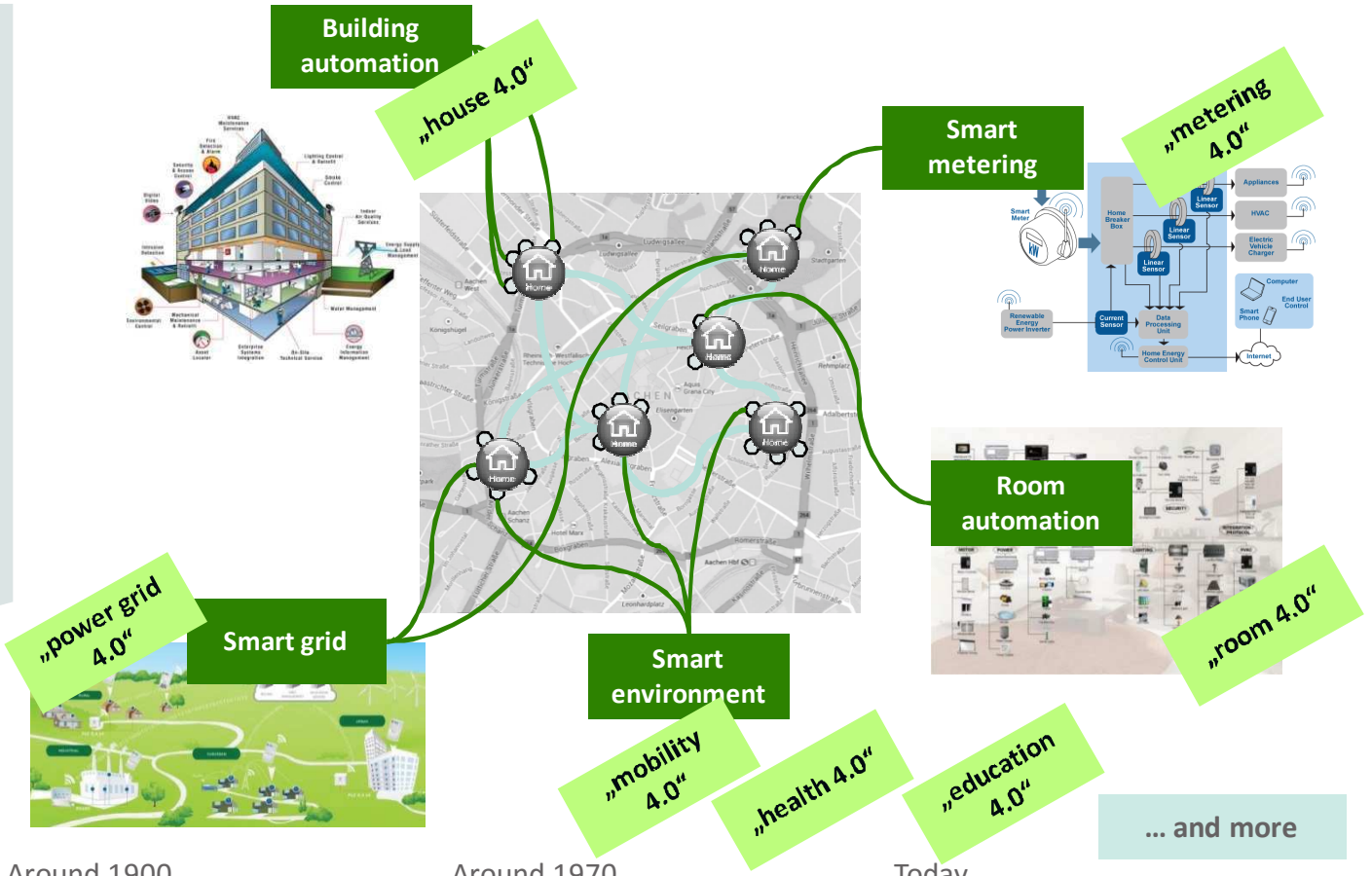
Smart Factory

IfU | IMA | ZLW | RWTH AACHEN UNIVERSITY

“Information Revolution” – Not reducable to Industry 4.0

“Industry 4.0 will address and solve some of the challenges facing the world today such as resource and **energy efficiency, urban production** and **demographic change.**“

Henning Kagermann et.al., acatech, 2013



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

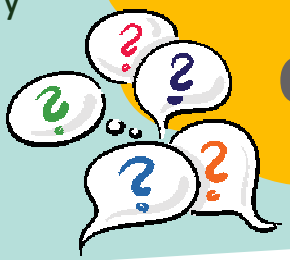
Around 1970
Digital Revolution
Digital computing and communication technology, enhancing systems’ intelligence

Today
Information Revolution
Everybody and everything is networked – networked information as a “huge brain”

And how do these systems work?

- **In the past, technological system have been the "image" of ourselves:** we did the design, the construction, the programming. The products "behaved" accordingly – as an extension of our imagination.

- **For the first time ever, we are facing systems which are capable of learning – even with consciousness.**
  Self-learning systems do not any longer stick to exactly the behavior they were designed with.
  We do not know exactly when and what they learn.
  However, to restrict the learning process to its "deterministic parts" would destroy most of their potentials.



?? Modelling?
Steering?
Controlling ??

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

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"

IfU IMA ZLW RWTH AACHEN UNIVERSITY

The vendor change around „cars“

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.

TESLA

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"

IfU IMA ZLW RWTH AACHEN UNIVERSITY

The vendor change around „cars“

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.

TESLA

Google: First autonomic car with street license, 2012

Google

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

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"

IfU IMA ZLW RWTH AACHEN UNIVERSITY

Outline

I. **The Age of Artificial Intelligence**
   - The Rise of Artificial Intelligence and its Relation to 4.0
   - Intelligent Self-learning Systems

II. **Society 4.0 and Work 4.0**
   - Changes of the Occupational Areas
   - Organizational Changes and Platform Economies
   - Artificial Intelligence changes Society

III. **Summary and Outlook**

Can machines learn?

? **Can machines learn to predict future states? To optimize tasks themselves?...**

YES, THEY CAN!

And if so, how can they do it? And can it be used in “real-world applications”?

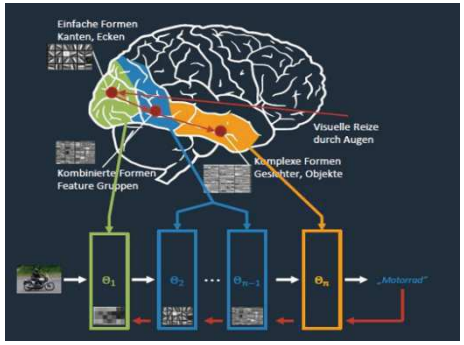
➔ How do machines learn?

A – Learning by observations and explanations

➔ Data-driven learning

B – Learning by doing - reinforcement learning

➔ Trial-and-error learning



C -> Deep Learning

➔ Deep Learning connected with Big Data is the breakthrough:
The machine knows what it is and what it wants; it is learning and reflecting its behavior

Example A – Learning by observations and explanations

! A “real-world application” – **Warp knitting machine**

➔ How does the Warp Knitting Machine learn? With 200 Agents designed with the democratic principle of Separation and Division of Power

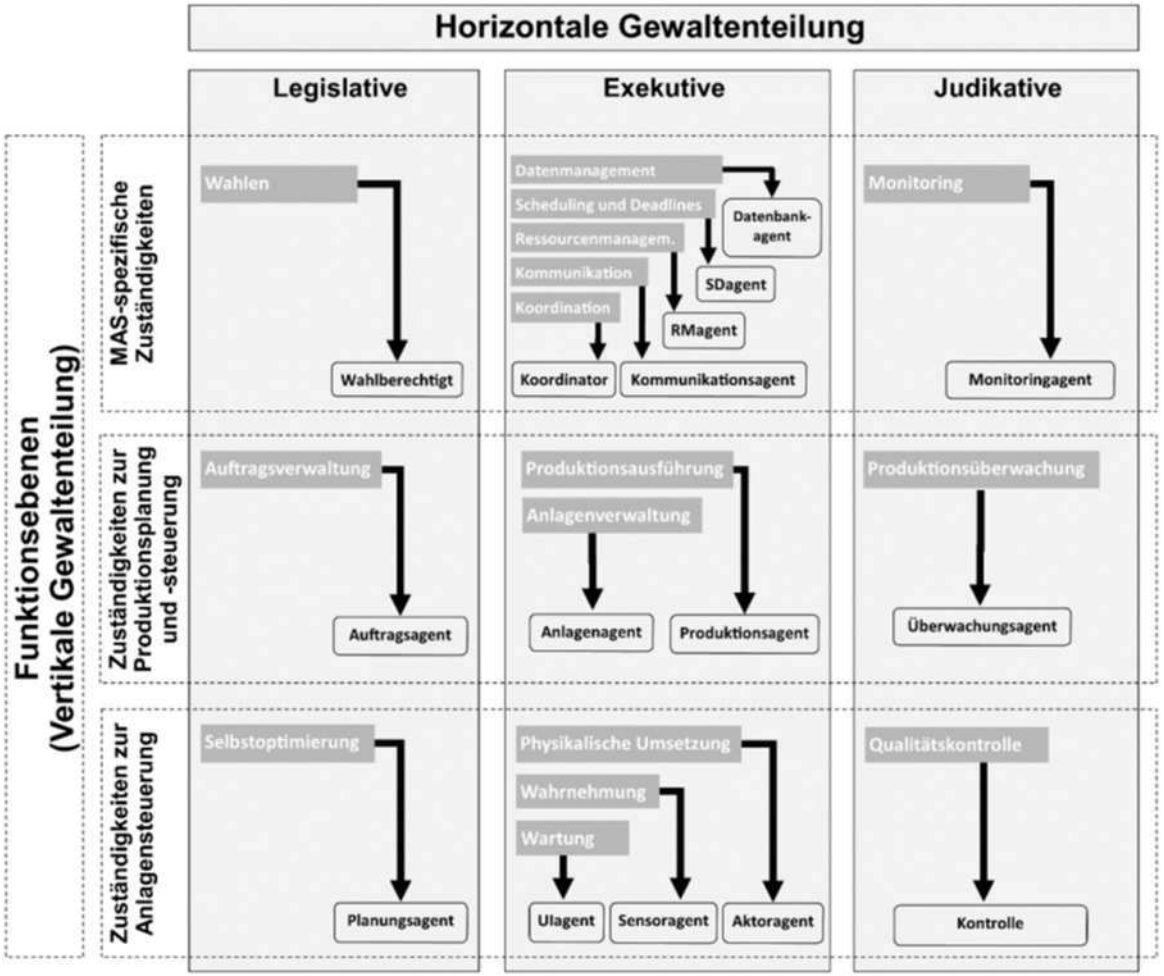
Design:

- **No SPS Control**
- No human training of the machine
- All functions are defined for the 200 single board computers, acting als agents

Quelle: Dissertation **Bahoz Abbas**: Verteilte Multi-Agenten zur Planung und Steuerung von Produktionsumgebungen auf Basis der Gewaltenteilung und Gewaltenverschränkung; Cybernetics Lab, RWTH Aachen, 2017

Example A – Learning by observations and explanations

! A "real-world application" – **Warp knitting machine**



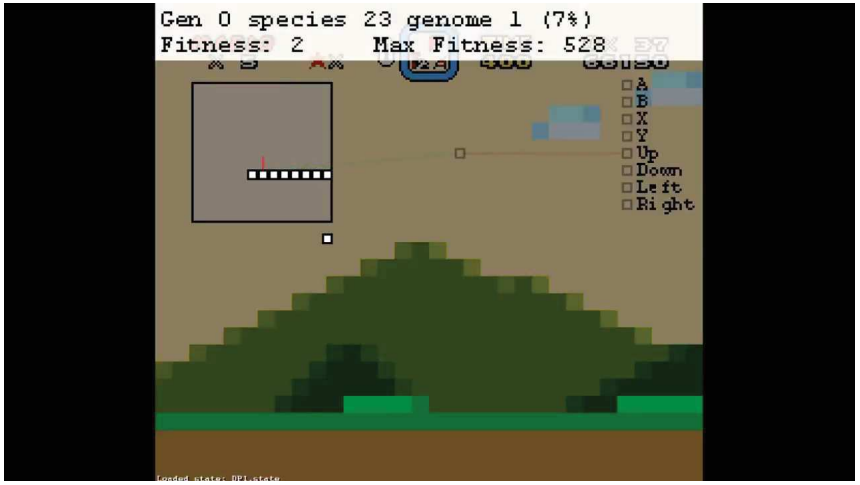
! **Result:**

100% reliability of individual agents within 800 ms (200 trials) without any quality loss

Self Optimization of the clutch quality is being proved – no "human help" is necessary

B – Learning by doing - reinforcement learning

? The Super-Mario: The machine learns how to solve a level - using an intelligent trial-and-error approach and rewards to learn actions



[SethBling, 2015]

Neuroevolution of augmenting topologies (NEAT) [Stanley, 2002]

- **Genetic algorithms on top of neural networks**
- At each **state** the system decides what **action** to do
- Actions are **rewarded** if Mario does not die in return
- Level progress by **evolving** neural networks

➔ **Reinforcement learning (R-learning)** is inspired by behaviorist psychology – maximizing the expected return by applying a sequence of actions at a current state (Minsky 1954)

Now, Human factor is

- reduced to very general, formal specifications of the neural network…
- However, human still influences the underlying representation model

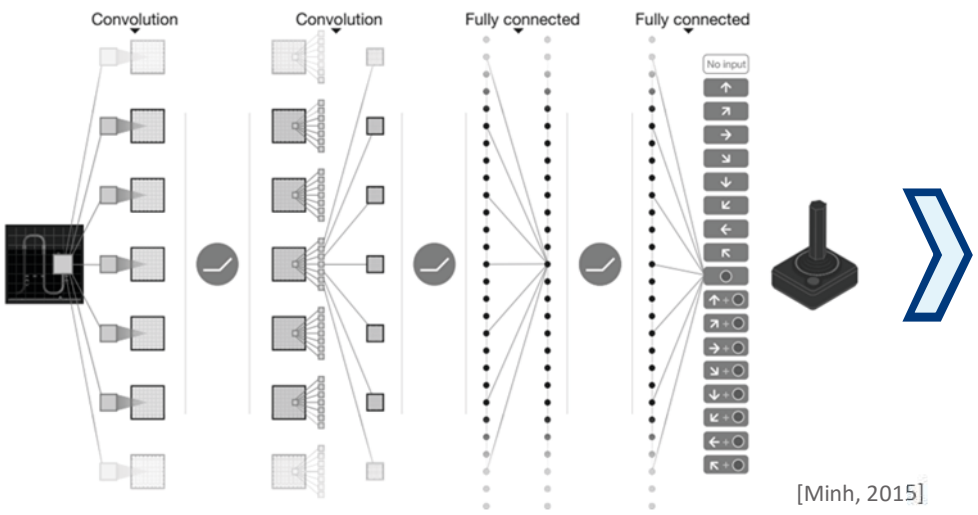
Human factor is "very small"!

IfU IMA ZLW RWTH AACHEN UNIVERSITY

Example C – Deep Learning

! "**Today**, computers are beginning to be able to **generate human-like insights into data**…. Underlying … is the application of **large artificial neural networks** to machine learning, often referred to as **deep learning**." [Cognitive Labs, 2016]

➔ Deep Q-Networks (also "deep reinforcement learning", Q refers to the mathematical action-prediction-function behind the scenes….): **Learning directly from high-dimensional sensory input**



[Minh, 2015]

[nature, 2015]

➔ **AI starts to develop strategies to beat the game**

➔ **Signs of "body consciousness"**

Human factor practically zero.

IfU IMA ZLW RWTH AACHEN UNIVERSITY

The creative artificial mind: AlphaGo Zero

! Go originated in China more than 2,500 years ago. 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 AI researchers. [adapted from Hassabis, 2016]

→ The problem: **2.57×10^{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.

Data-driven learning

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)

Reinforcement learning

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

[Hassabis, 2016]

By 19/10/2017, AlphaGo Zero has been introduced.
...
Human factor practically zero.

IfU IMA ZLW RWTH AACHEN UNIVERSITY

Robotinos competition

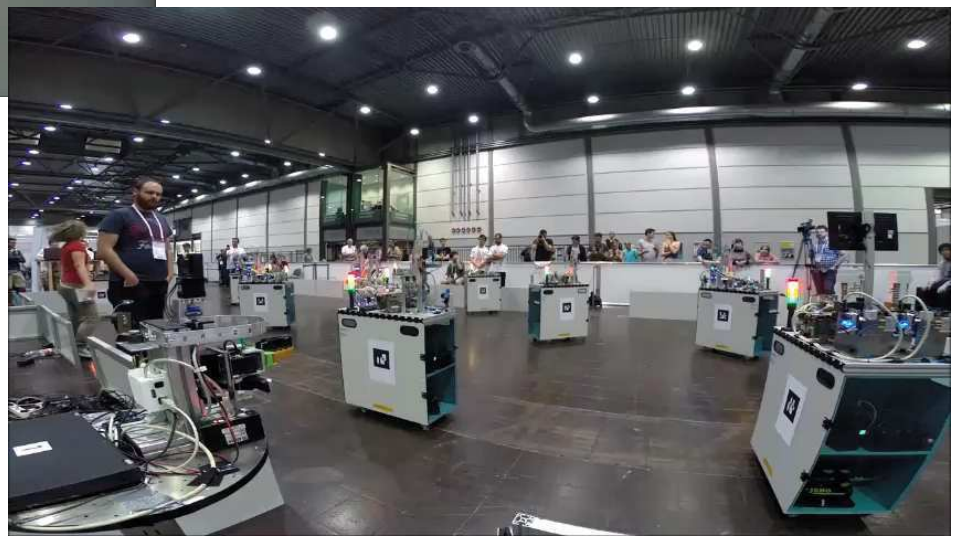
http://www.carologistics.org/

Mobile transportation robots from flexible routing

Competitions robocup:

2014 -2017:

4x Winner of the World Cup



Model of cooperative learning:

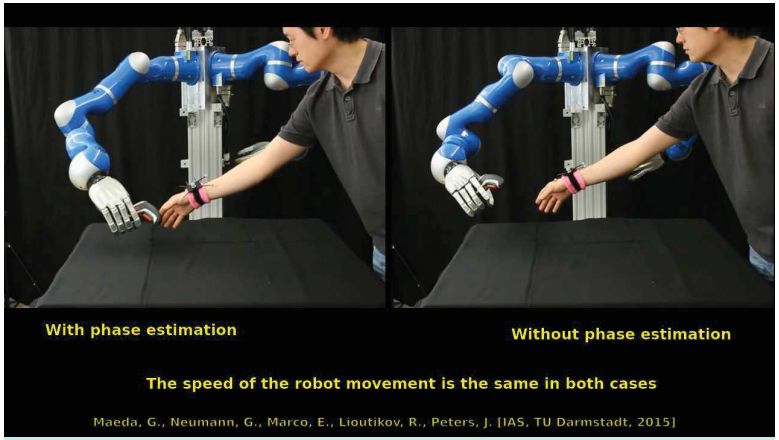
- Totally decentralized
- Strong cooperation
- No ”hard coded components“
- Intense information sharing
- Cooperative decision making
- Re-planning during tasks

Picture: IfU an der RWTH Aachen, Jahresbericht 2016

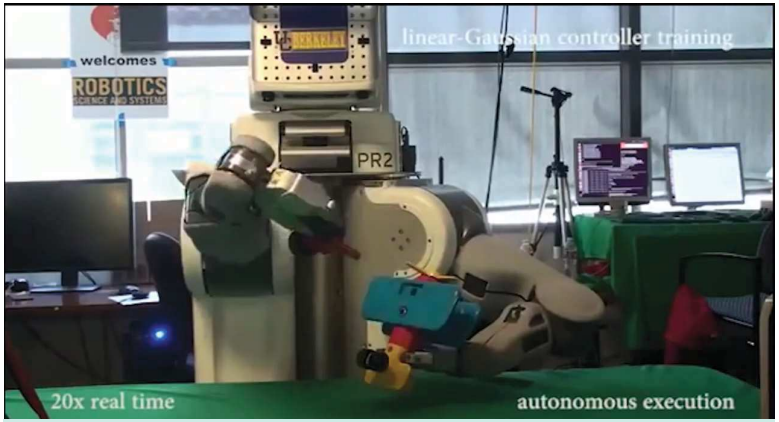
There are lots of industrial applications

learning and optimization of motions

[Intelligent Autonomous Systems, 2015]



“pro-training” for human-machine interaction



learning and executing complete assembly tasks

[UC Berkeley, 2015]

Outline

I. The Age of Artificial Intelligence

- The Rise of Artificial Intelligence and its Relation to 4.0
- Intelligent Self-learning Systems

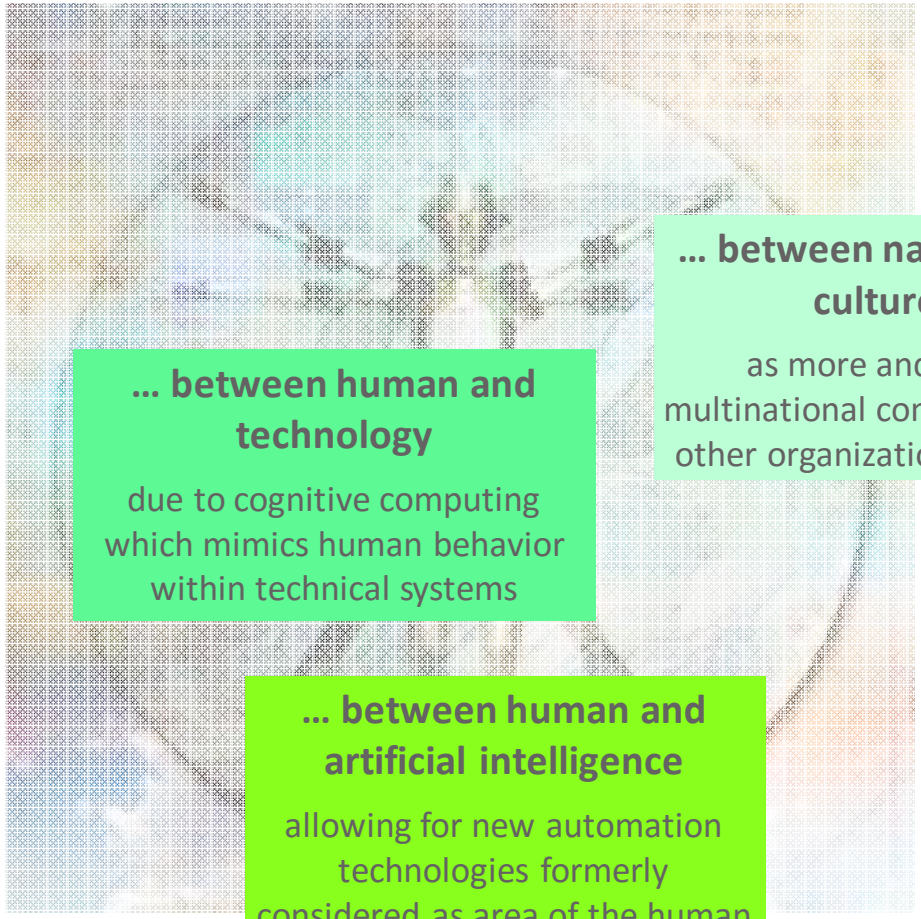
II. Society 4.0 and Work 4.0

- Changes of the Occupational Areas
- Organizational Changes and Platform Economies
- Artificial Intelligence changes Society

III. Summary and Outlook

Outline

Dislimitation if “work” and “life” …



… between human and technology

due to cognitive computing which mimics human behavior within technical systems

… between nations and cultures

as more and more multinational companies and other organizations emerge

… between human and artificial intelligence

allowing for new automation technologies formerly considered as area of the human

… between different organizational areas

as e.g. production, intralogistics and external logistics, structures getting “fluid”

… between different scientific fields

driven into interdisciplinarity as a large number of new subjects can not be classified along “the old lines”

… between virtuality and reality

due to through ubiquitous communication channels and augmented and virtual reality

The creative artificial mind changes all jobs

White collar jobs

… are under massive change due to the enhancement in AI, here the impact often hits "**middle class jobs**"

Decentralized platforms

… with automated consensus models (e.g. block chain) take over complex administrative tasks e.g. in **judiciaries**

High qualified jobs

… as e.g. health professionals face already the taking over through AI in certain fields by Watson, Google Flu, etc.

IBM Watson

Social robots

… will become capable of taking over even complex tasks with personal presence as in **health or home care**

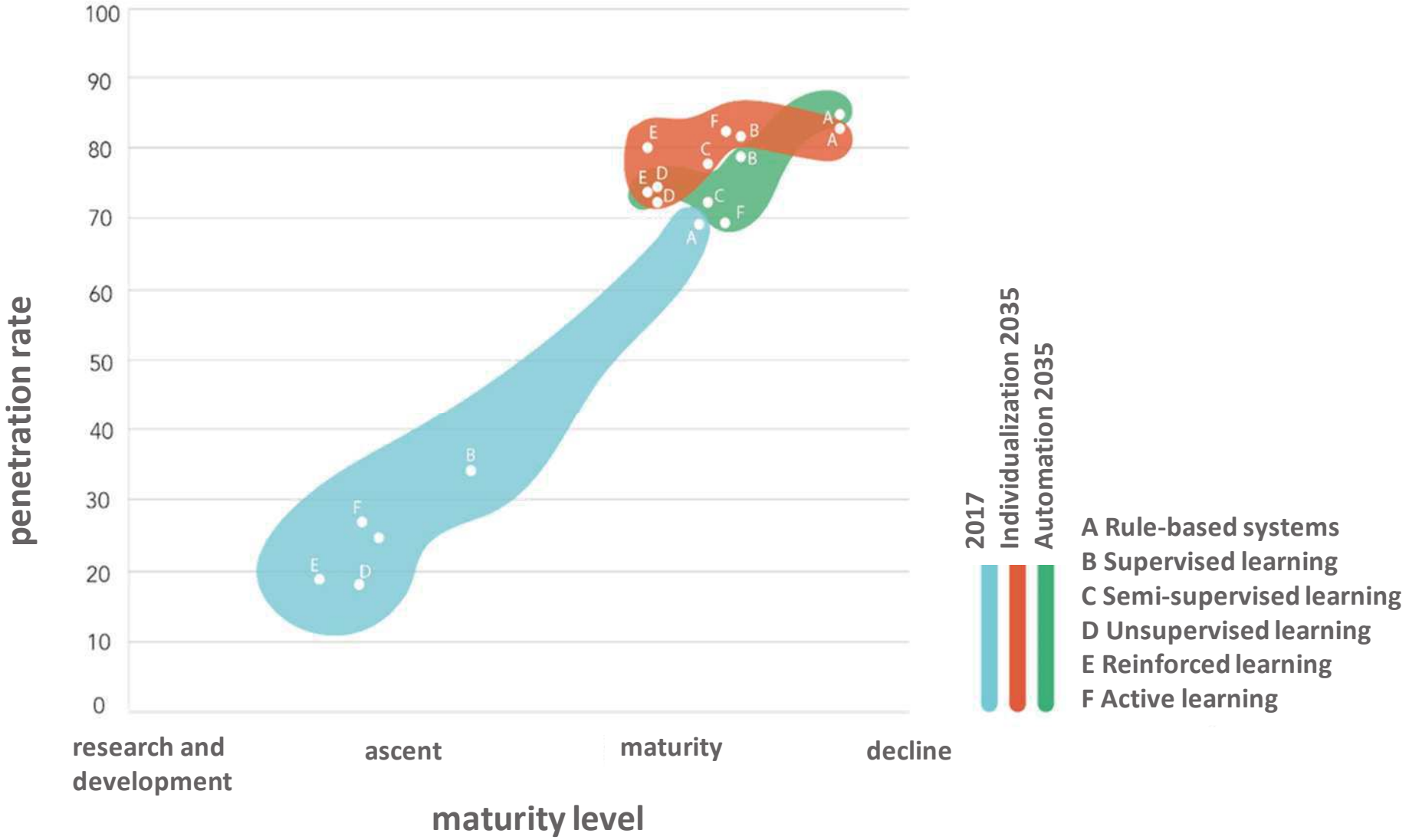
Autonomous systems

… as autonomous cars and more enhanced production technology will **change the blue collar** – low qualified as well

Virtual and augmented environments

… allowing **for new international players**, even in tasks requiring humans and presence

AI influencing jobs



Future Jobs

Virtual Manufacturing Engineer

Simulation of product lines for process optimization and cost reduction

Qualifications: engineering, manufacturing, process simulation, spatial and constructive imagination

Robotics- and Automation Specialist

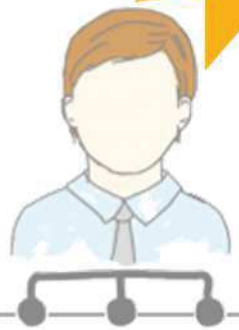
Developing all software applications for data processing and control of robots

Qualifications: software skills, knowledge of robotics and automation

Digital Transformation Manager

Leads the digital project portfolio

Qualifications: management, strategic thinking and leadership skills



Predictive Maintenance Specialist

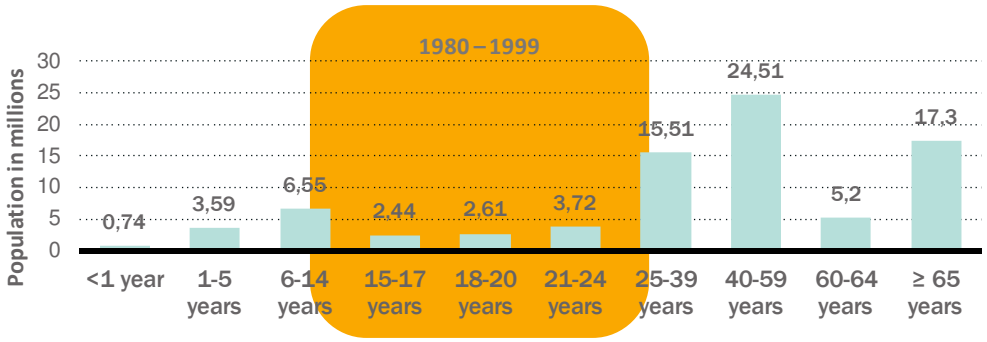
Preventive maintenance of machinery

Qualifications: engineering, manufacturing, root cause analysis

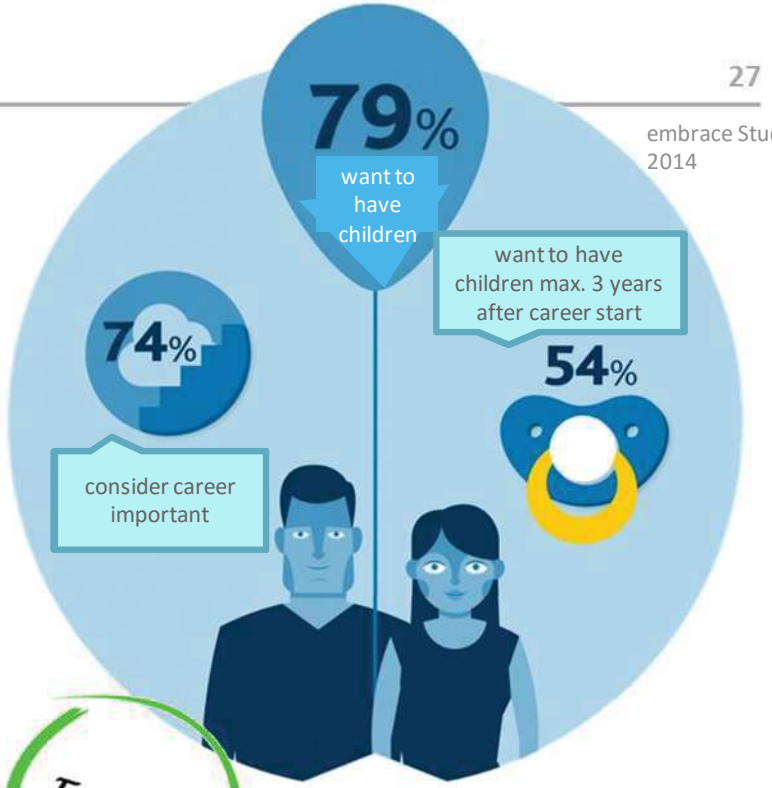
Changes of the Occupational Areas

Gen Y entering the market

Statista (2015)



embrace Studie 2014



Outline

I. **The Age of Artificial Intelligence**
   - The Rise of Artificial Intelligence and its Relation to 4.0
   - Intelligent Self-learning Systems

II. **Society 4.0 and Work 4.0**
   - Changes of the Occupational Areas
   - **Organizational Changes and Platform Economies**
   - Artificial Intelligence changes Society

III. **Summary and Outlook**

Towards decentralized lot size 1

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

- **Heterogenous player modeled as multi agent concept**
- **Models from biology and social sciences**
- **Basis on Autopoiesis & embodiment theory**

Product agitates as “super-agent”:

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

outside world

fabrication

transport unit

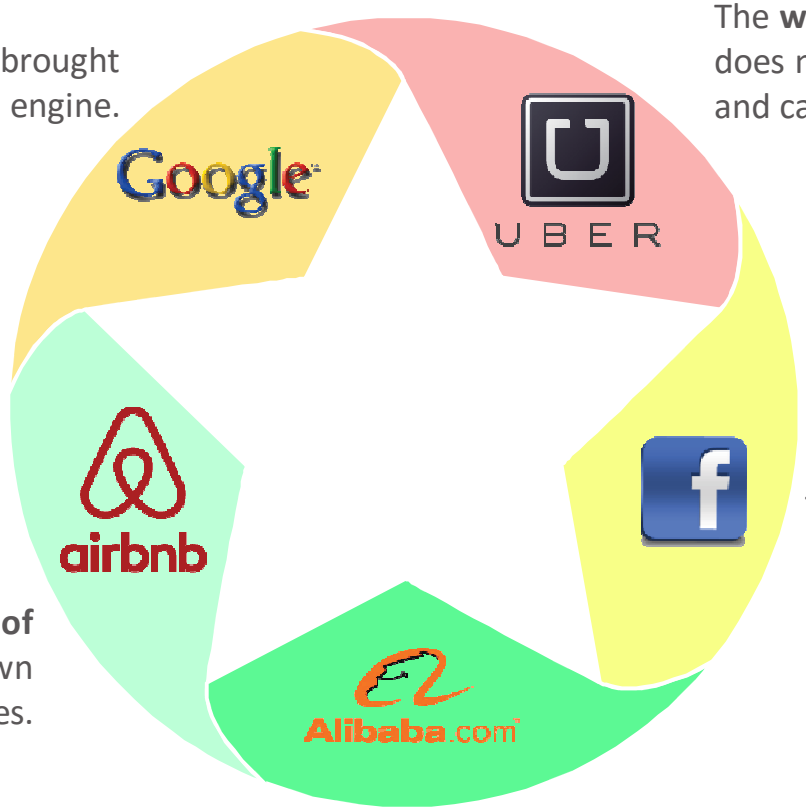
production unit

virtual service provider

New business models

World's first autonomous car was brought to the market by a search engine.

The **world's largest taxi company** does not have its own drivers and cars.

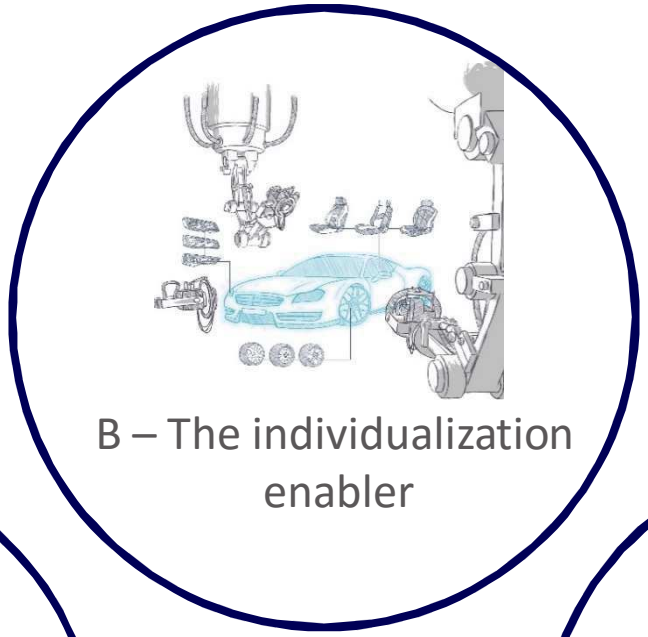


The **world's largest media provider** does not create its own content.

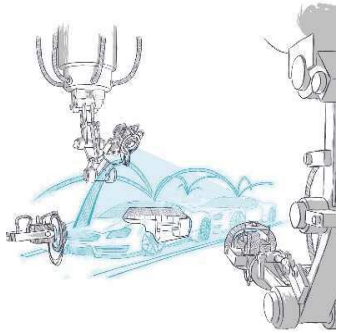
The **world's largest provider of accommodation** does not have its own properties.

The **world's largest retailer** does not have its own storage space.

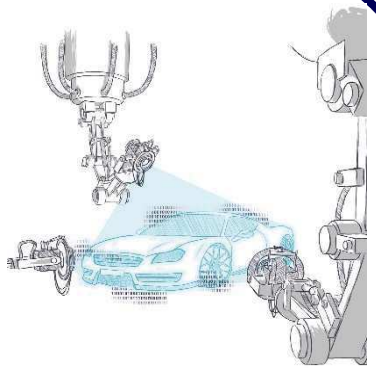
What does that mean for the Automotive Industry?



B – The individualization enabler



A – The mobility provider



C - The data giant

Bringing it together to a Reference Scenario

Extremszenario

Individualization

- Island production is the most important form of production
- Car not only transport but also work and living space
- High individuality & product diversity
- High demands on the adaptability of the production
- Processing of customer requests and product changes in real time
- Many non-routine activities through high product diversity

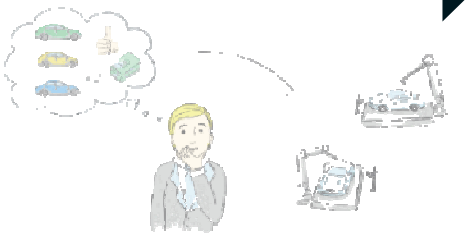
Extremszenario

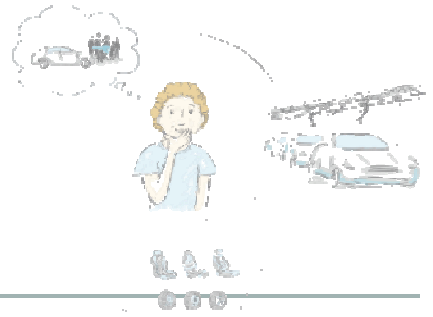
Automation

- Assembly line production is the most important form of production
- Value loss of status symbols car
- Increasing the importance of sharing concepts, especially in urban areas
- Former automotive manufacturers as mobility providers
- Increasing demand for standardized vehicles
- Establishment of highly autonomous systems
- Increase of routine assembly tasks

Reference Scenario

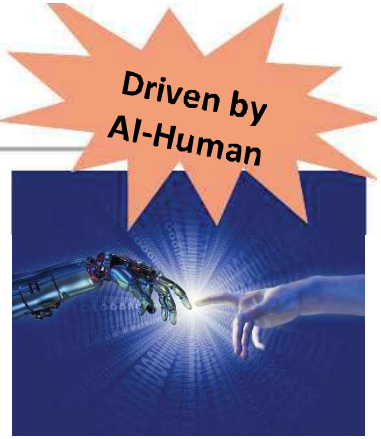
- **Combine the advantages of assembly line and island production**
- **Increasing the importance of new mobility concepts**
- **Development of new business areas**
- **Constantly increasing demand for individual products**
- **Increase in human-robot collaboration**





Organizational Changes and Platform Economies

Along the production & supply chain…



Creative learning from previous designs

AI-supported machine ramp Up

…

Real and model-based world combined: Integrated planning

Transparent Live Cycle

Development & planning

In production

After sales & maintenance

Flexible task management

Predictive and prescriptive

…

Cobot workplace design and workplaces

Creative adaptive machine regulation

Outline

I. **The Age of Artificial Intelligence**
   - The Rise of Artificial Intelligence and its Relation to 4.0
   - Intelligent Self-learning Systems

II. **Society 4.0 and Work 4.0**
   - Changes of the Occupational Areas
   - Organizational Changes and Platform Economies
   - Artificial Intelligence changes Society

III. **Summary and Outlook**

New fields of action for jurisprudence [law]

! **Field of work** is about to change due to the capability of technical systems and artificial intelligence to take over lots of tasks, which are so far performed by lawyers

! **New fields for new technologies**, e.g. insurances and other legal and ethical effects for autonomous cars, medical robots etc.

! **New questions around intangible properties,** e.g. intellectual property: due to speed of innovation and digitalization of information, new rules for open source, …

! **New ethical questions for non-human systems**, either hybrids or purely technical ones (but with consciousness, emotions)

Changes to morality and ethical standards

Predictive policing:
burglary pre-diagnostic

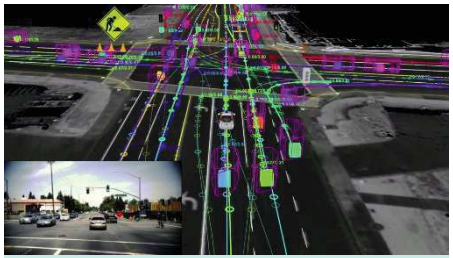
Predictive policing:
crime-alert agent

Prediction is based on probability.
Is intention already accusable?

→

Design of society:

- **Changes induced by 4.0 create new processes and models**
- **Important questions in all political fields where "questions of justice" are addressed**



Cars with morality:
collision optimization

Algorithms do - so far - not design themselves.
Which legal structure and which ethical codex are they based on?

The Change to Hybrid Intelligence

On the long term, all technical objects in our world will become intelligent and will have self-awareness.

All essential technical objects will have a **life-long learning process, interacting with their "technical neighbors" and with humans.**

→ **Design of society:**

- **A new world has to be designed actively on the basis of our values – before it is irresponsibly designed by others.**

The omnipresent and discret interaction between the digital shadows of technology and humans **will dominate all aspects of communication.**

Outline

I. The Age of Artificial Intelligence

- The Rise of Artificial Intelligence and its Relation to 4.0
- Intelligent Self-learning Systems

II. Society 4.0 and Work 4.0

- Changes of the Occupational Areas
- Organizational Changes and Platform Economies
- Artificial Intelligence Changes Society

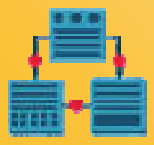
III. Summary and Outlook

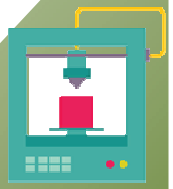
Artificial Intelligence

- … takes over not only routine tasks, but becomes also more creative
- … supports humans in physical and cognitive work issues
- … becomes a own juridical identity

- … individualized lifestyle and life planning
- ..lots of juridical, moral and ethical questions to be solved

- … new interdisciplinary job fields lead to changing qualification
- … new understanding of hierarchy and distance





Society

Work

At the time of Gutenberg the **mass media Book** Printing initiated **a large religious, societal and political change**

Machines, cars, objects of daily life will have their one consciousness. This is – as well as the just-in-time worldwide networking - a completely new dimension.

→ **The biggest disruptive innovation of society since Gutenberg (1450 - 1460) is happening just now**

This digital transformation towards **"digital agents, digital shadows, digital twins"** etc. is a global and local revolution. It will redesign all areas of our life extremely. It is unavoidable.

The digital universe with intelligent machines and networks – having self-awareness **– is a huge chance to reinvent our way of living, working and learning.** We should manage this in a better way than our forefathers did during the time of Gutenberg and Luther.

Thank you!

Univ.-Prof. Dr.-Ing. Klaus Henning
Senior Advisor of Cybernetics Lab IMA/ZLW & IfU
klaus.henning@ima-zlw-ifu.rwth-aachen.de

Univ.-Prof. Dr. rer. nat. Sabina Jeschke
Head of Cybernetics Lab IMA/ZLW & IfU
sabina.jeschke@ima-zlw-ifu.rwth-aachen.de

Co-authored by:

Prof. Dr.-Ing. Tobias Meisen
Junior Professor "Interoperability of Simulations"

Dr. rer. nat. Sebastian Stiehm
Head of research group knowledge engineering

Dr. rer. nat. Frank Hees
Deputy Head of Cybernetics Lab IMA/ZLW & IfU

Dipl.-Ing. Thomas Thiele (Mech. Eng.)
Head of research group production

Sarah Müller M.Sc.
Research group knowledge engineering


Thank you!