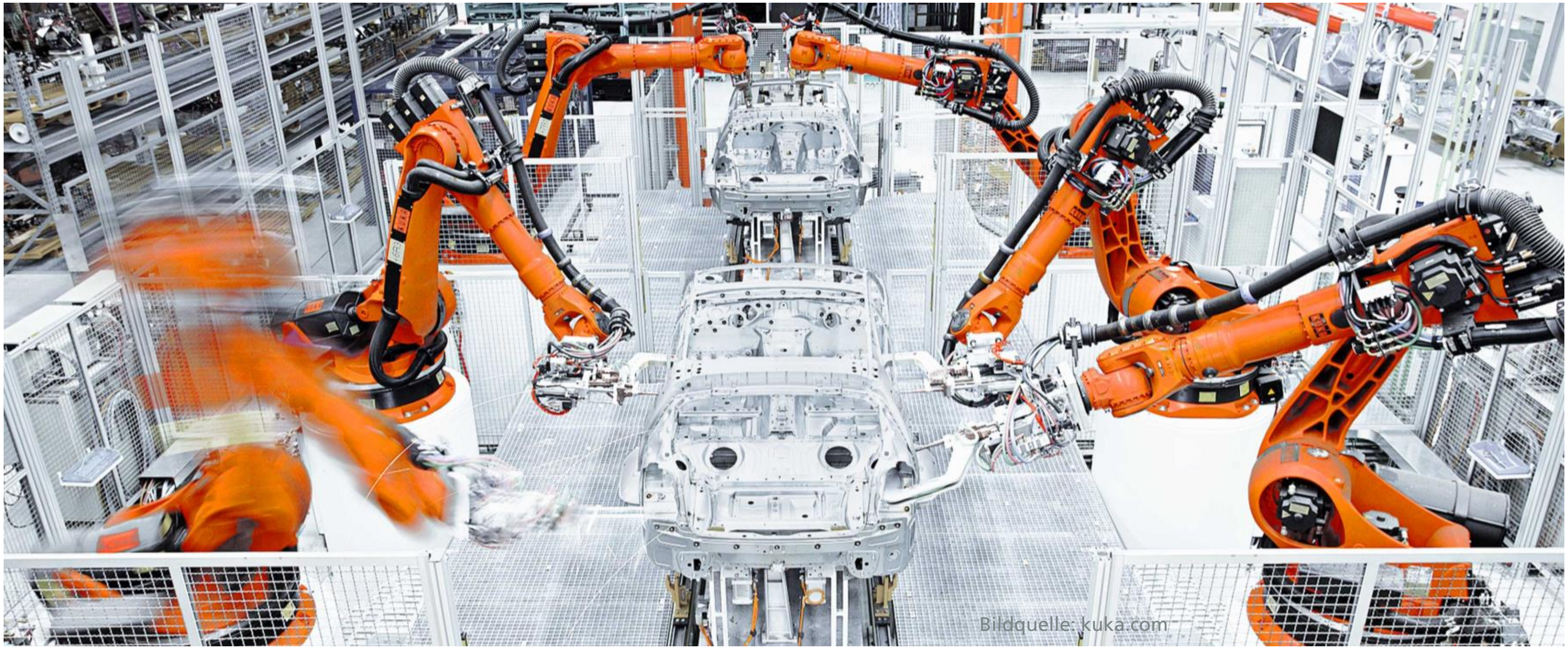
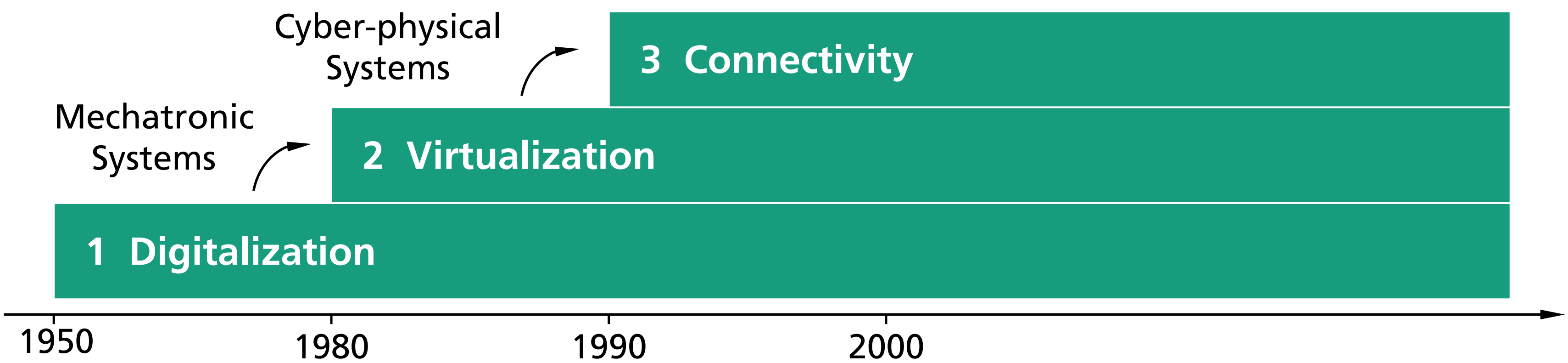
DIGITAL TRANSFORMATION IN AUTOMOTIVE INDUSTRY – CONSEQUENCES FOR BODY IN WHITE PRODUCTION

Prof. Dr.-Ing. Thomas Bauernhansl
May, 2019



Development Stages of the Digital Transformation

From digital image to Cyber-physical Systems



Digital image of analog processes (e.g. NC technology, 2-D CAD, MRP/ERP)

Digital modeling of processes (e.g. CAD/CAM, FEM, digital factory)

Integration of all value creation processes via broadband telecommunication (e.g. industrial IoT, cloud computing, CPS, 5G)

Combination of classic technologies and artificial intelligence create autonomous, self-organizing systems (e.g. autonomous transport systems, autonomous robots)

source: Fraunhofer IPA

CPS architecture prevails (1/2)

Everything becomes a smart phone, the vehicles ...

source: motor-talk.de

Vertical Integration

core elements of the fourth industrial Revolution

Infrastructure (physical, digital)

Cyber-physical System

Product Life Cycle (valuable = personalized + sustainable)

Interaction

Physical Systems (act, sense, communication) | **Human Beings** (decide, create, communicate)

Reflection

Digital Shadow (real-time model of everything)

Transaction

Software Service (machine skills, Apps for humans, platform services)

Interoperation

Cloud-based Platforms (private, community, public)

Prescription

Analytics (Big Data/machine learning)

Communication

Internet of Everything (human beings, services, things)

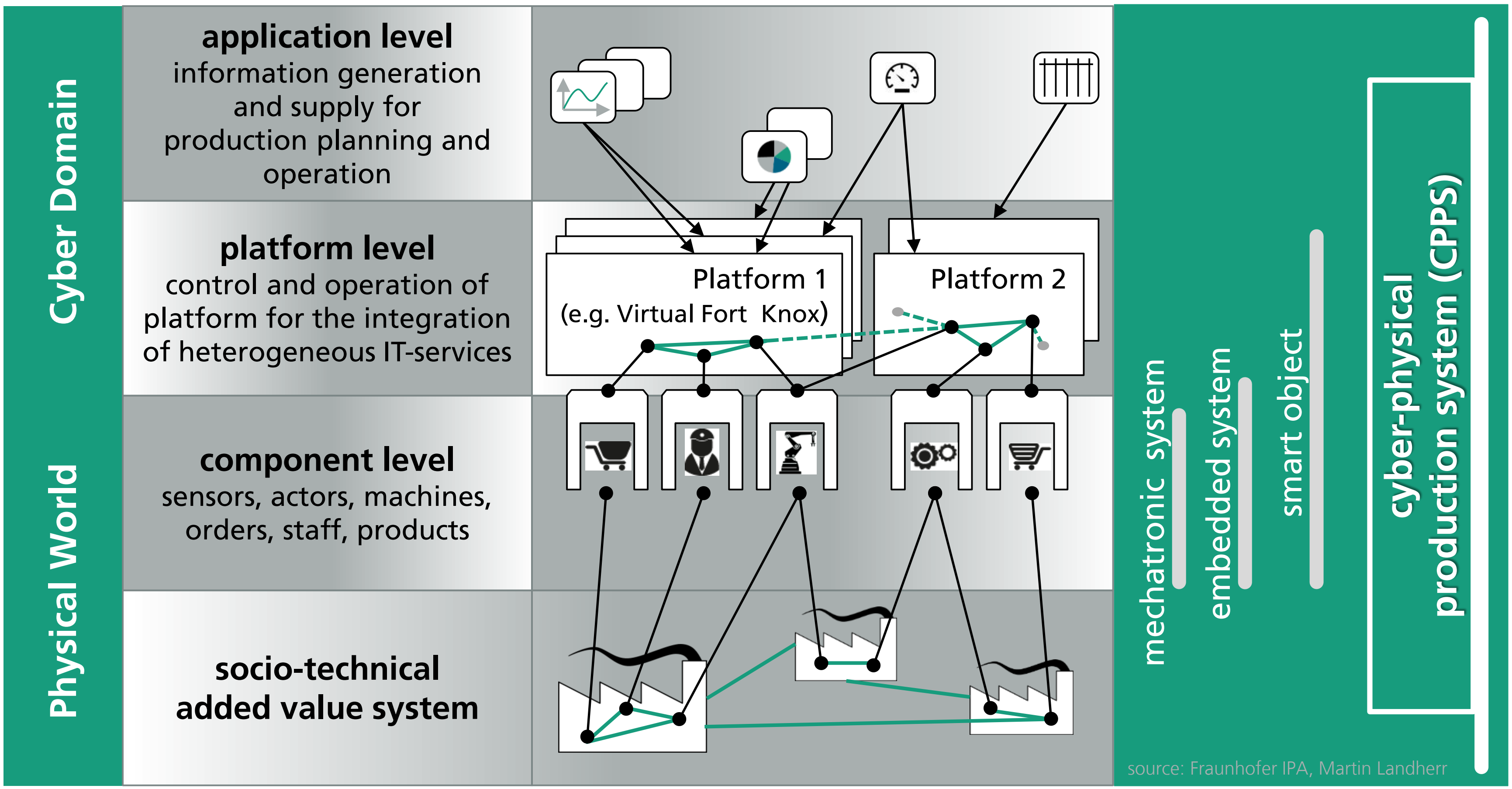
CPS architecture prevails (2/2)

… and the means of production

source: Fraunhofer IPA

Cyber-physical Production Systems (CPPS)

The tool for the digital Shadow of Production



Networked Mobile Navigation in Industrie 4.0 Context
Cloud navigation

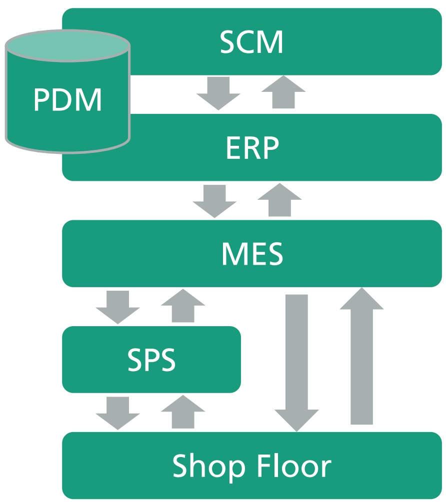
Fraunhofer
IPA

Cloud navigation for mobile robots
in intralogistics applications

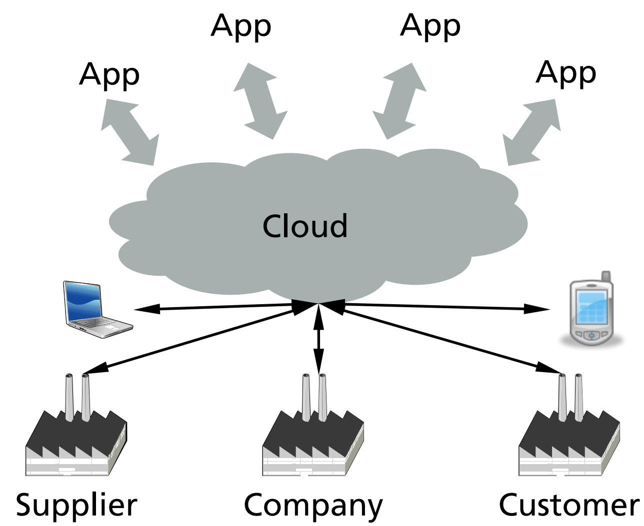
source: youtube.com/watch?v=r7KjHMeic2I

Shift to Cloudbased Service Platforms

IT system architecture today



IT architecture in future



- Inflexible systems that are linked through interfaces
- Introduction and modifications are time-consuming
- Organization-specific or factory-specific designs, that complicate collaborations

➔ **Pipeline Business Models (B2B/B2C)**

- Illustration of the requirements of applications
- Fast and easy adjustment to change
- Collective access to relevant data

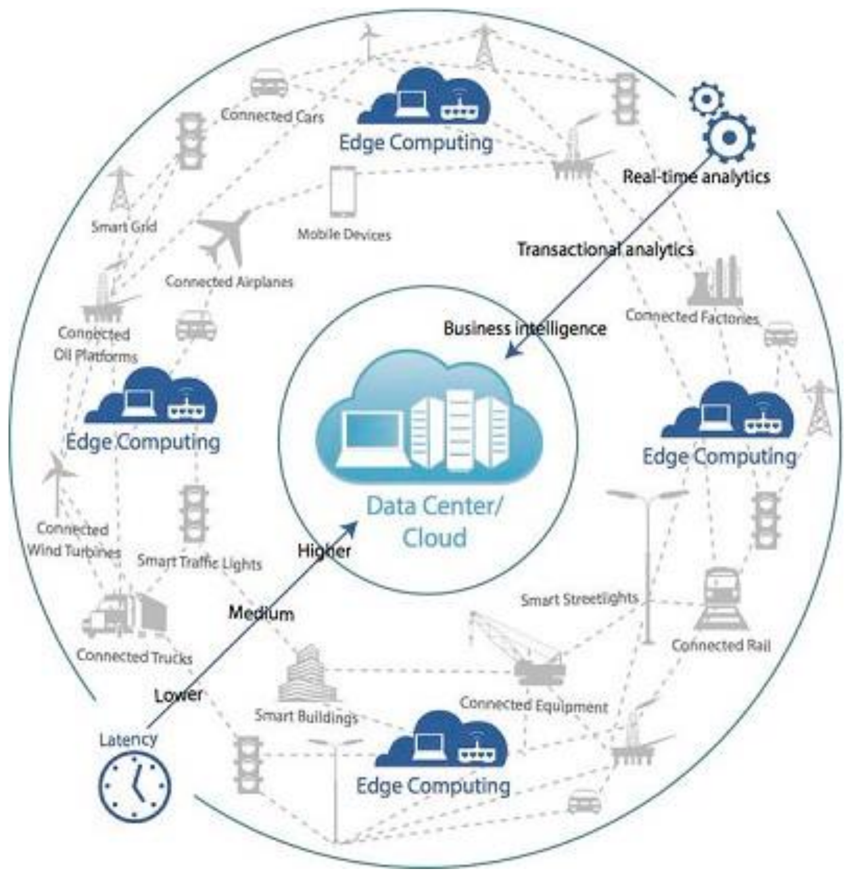
➔ **Platform Business Models (B2U)**

source: Fraunhofer IPA

Edge & Fog Computing

Deployment of software services close to data sources

- Instead of »data to the cloud«, »software service to the data«
- Data processing directly at the source
- Hard real time systems operate at the edge of the network
- Always online ist not neccessary
- Lower reqiriements concerning infrastructure (latency, bandwidth, safety,…)
- Focus: Life cycle management of software services in heterogenous infrastructure



source: Cisco, 2014

Automation Architectures as core of Manufacturing IT-Solutions

3 scenarios for future solutions

Evolution

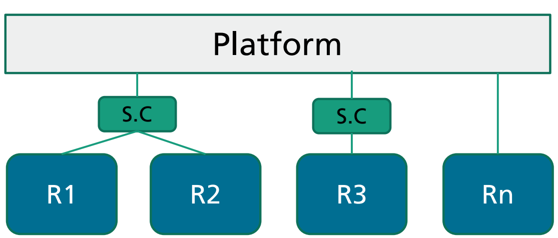
- **Structure: Static and local**
- Real, non-virtual structures with platform connection
- PLC with IoT-Gateway (Cloudplug, smart connector) or direct OPC-UA Connection
- »Data to cloud«-approach no hard real time
- Transparency and Monitoring functions based on historical data

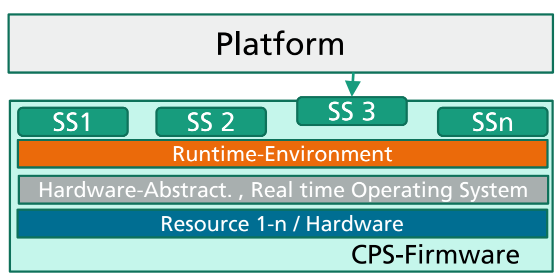
Progression

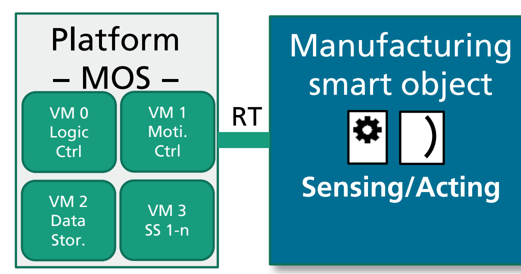
- **Structure: partly dynamic, localy distributed and virtualised**
- Virtualised Configuration on platform
- Software defined functionalities independ of PLC
- »Software service to data«-approach (hard realtime)
- Advanced functions based on Information sharing

Revolution

- **Structure: Dynamic and instantiated on platform**
- Full virtualization of all non process relevant components
- Fully software-defined control
- »Platform as Operating System«-approach (hard real time operating system)
- Intelligent servies based on real time communication



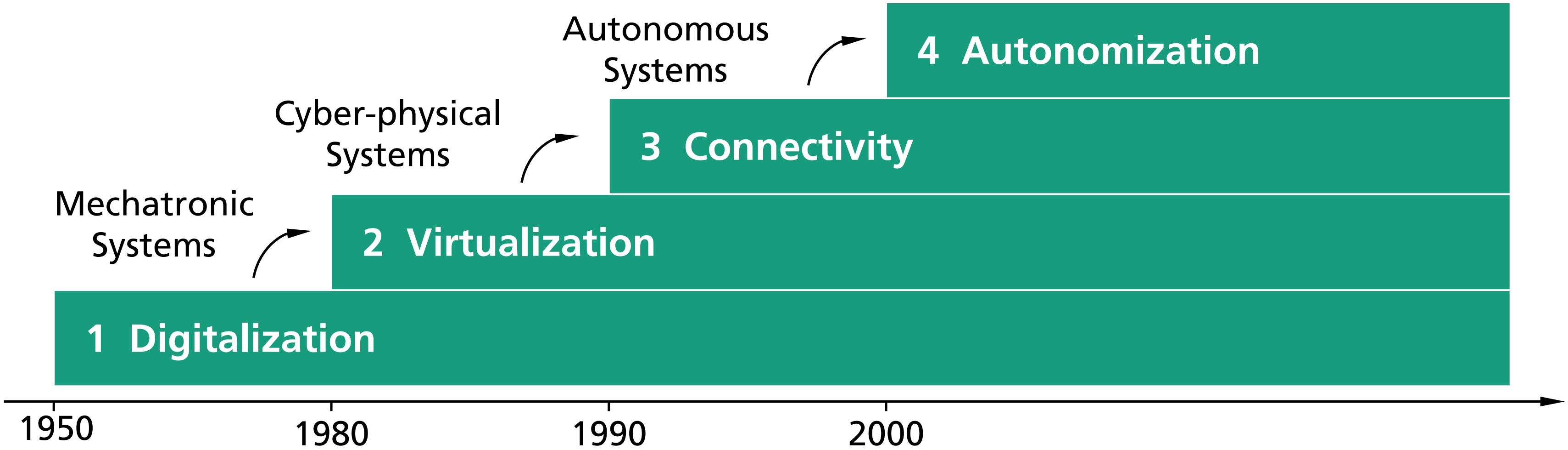




R 1-n Resource, **S.C.** Smart Connector, **SS 1-n** Software Services, RT Real Time, **MOS** Manufacturing Operating System

Development Stages of the Digital Transformation

Next step Autonomization leads to Cognitive Production Systems



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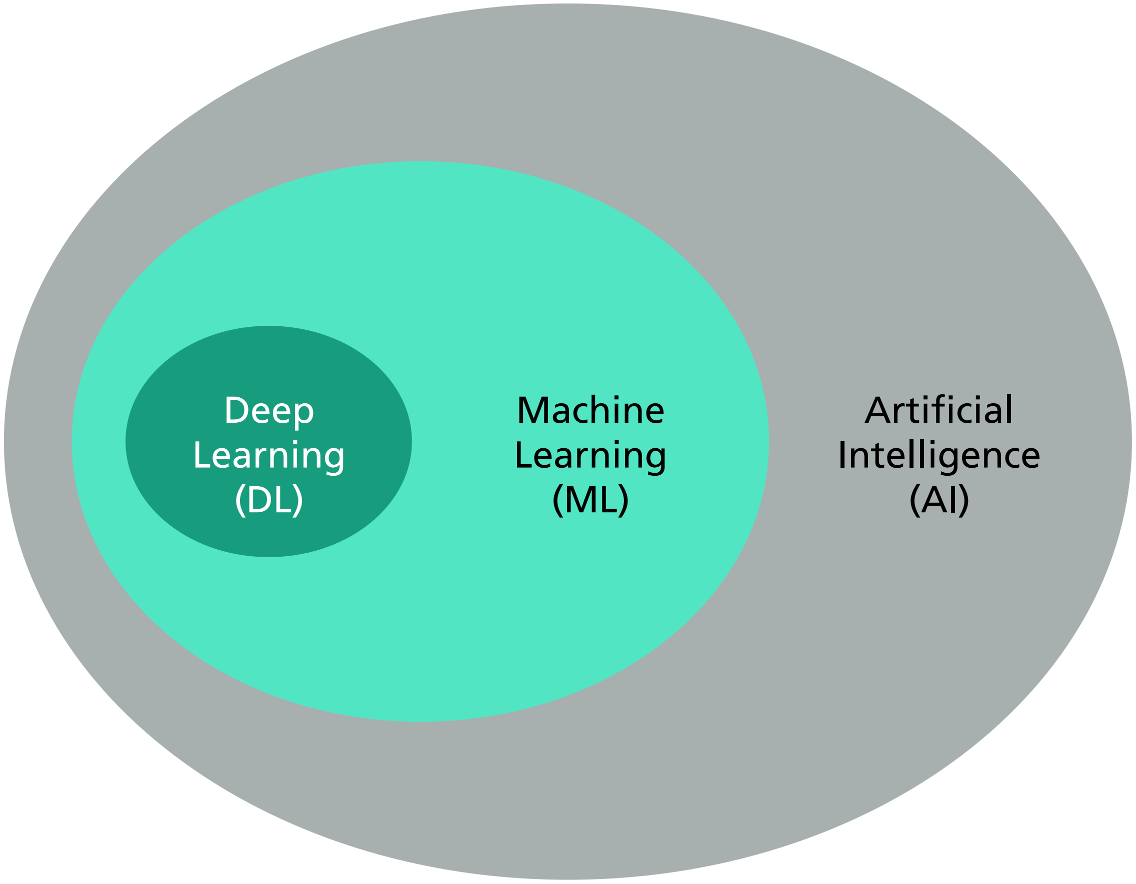
source: Fraunhofer IPA

Artificial Intelligence, Machine Learning, Deep Learning

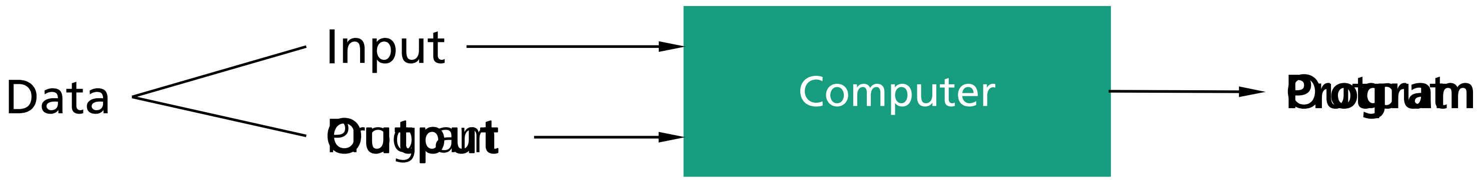
Venn Diagram



source: Fraunhofer IPA, Marco Huber

Machine Learning (ML)
Concept and purpose

Traditional Data Processing | **Machine Learning**



Problem: Writing a program is the bottleneck!

A. Samuel, 1959: »Machine Learning is the field of study that gives computer the ability to learn without being explicitly programmed.«

→ Learning from **examples** → **generalization**

When is machine learning appropriate?

- It is difficult/impossible to model cause-effect relationships or they are even unknown
- Optimization by means of physical models is too demanding

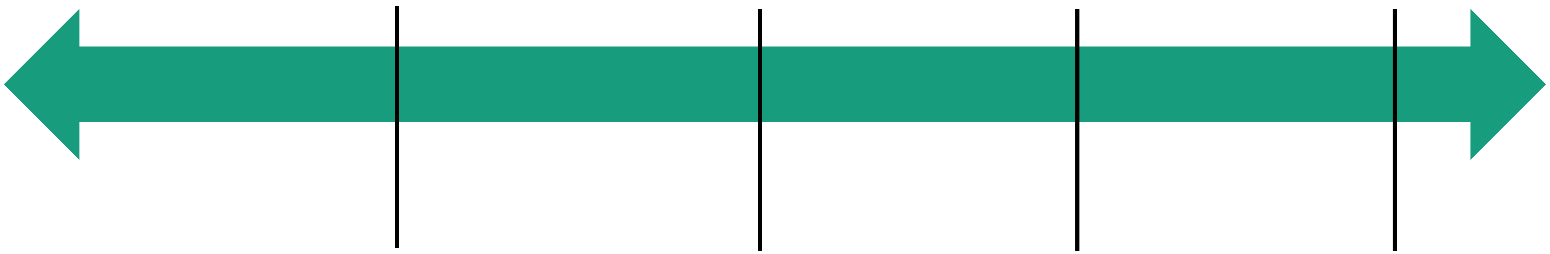
source: Fraunhofer IPA, Marco Huber

Accuracy Matters

Data quality opens up opportunities for B2B business models

Low demand

High demand



Recommendations in webshop

Insurance, finance

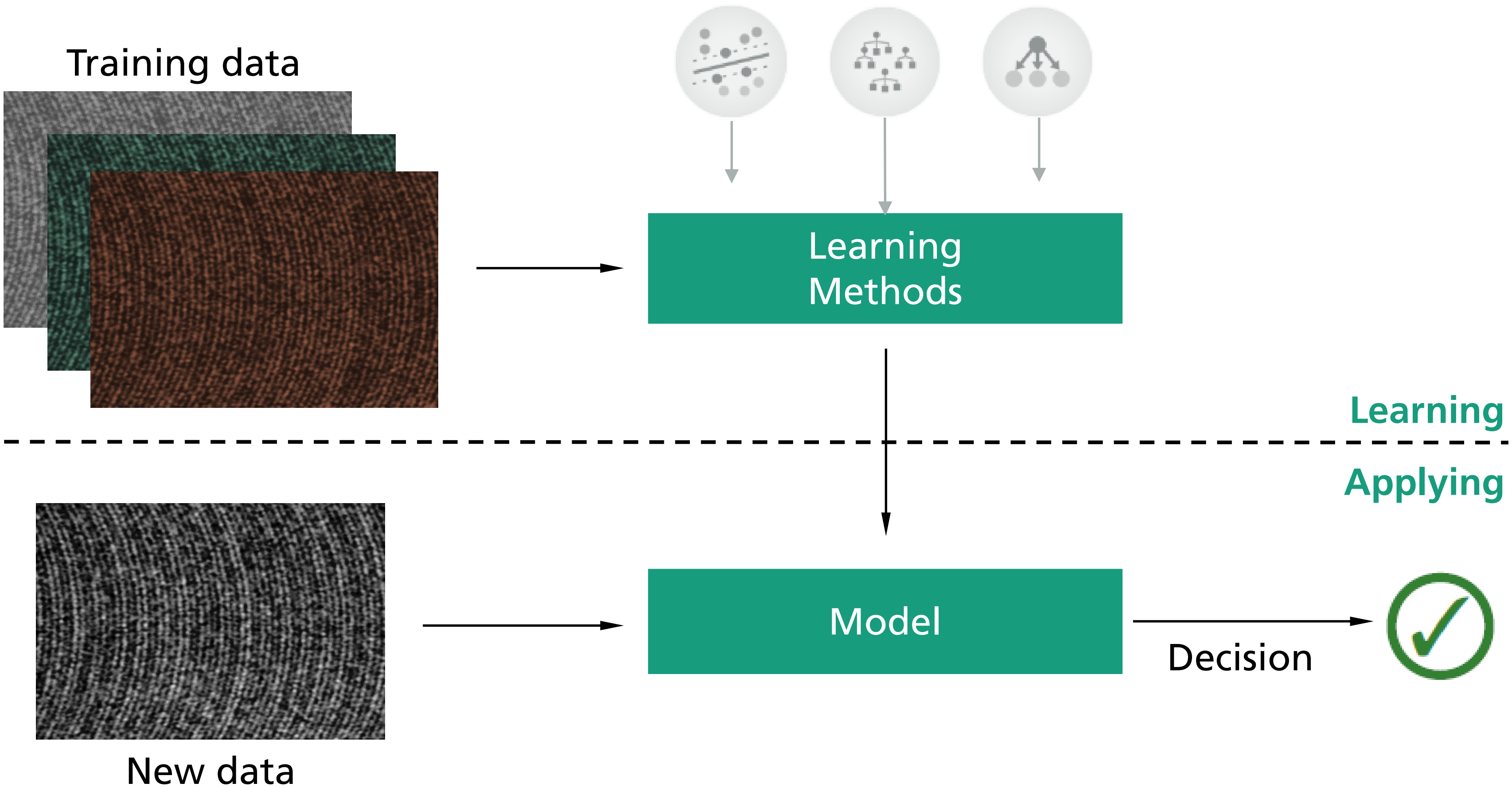
Production

Health care, self-driving cars

source: Fraunhofer IPA, Marco Huber

Learning from Data

Concept of learning and applying



source: Fraunhofer IPA, Marco Huber

Main fields of ML-application

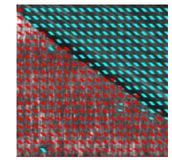
Case Studies of Machine Learning for Smart Production Systemes

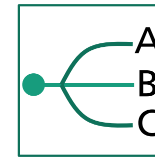
Case Studies

Classification

Separation of features

- Is this A, B, C …?

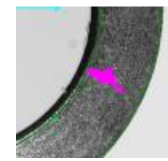


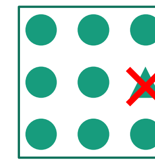


Detection of Anomalies

Outlier Detection:

- Is this OK; does this belong here?

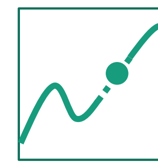




Regression

Prediction:

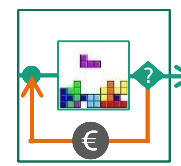
- How many? Which state?



Reinforcement Learning

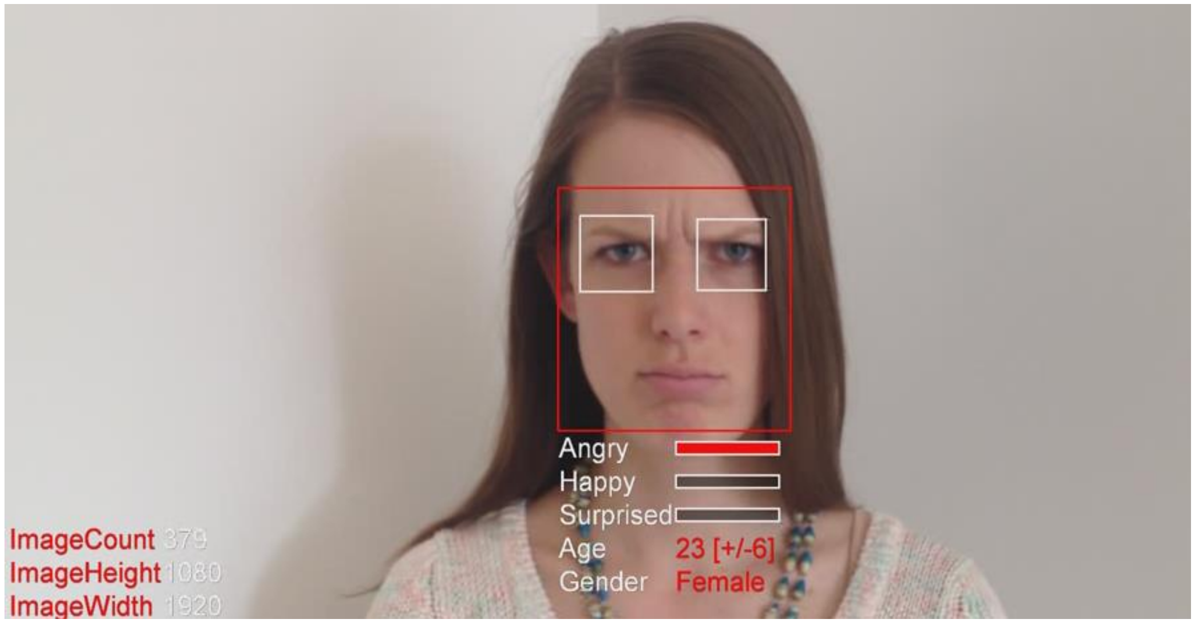
Learn proper policy

- Was that well done?



source: Fraunhofer IPA

Classification: SHORE^{TM} Technology Overview
Real-Time Facial Analysis



- Sex
- Age
- Emotions
- Mouth open/closed
- Eyes open/closed
- Head pose
- Profile detection

Fraunhofer
IIS

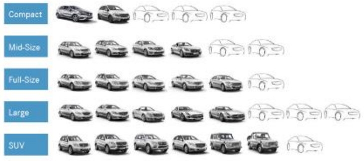
Trends in Automotive Industry

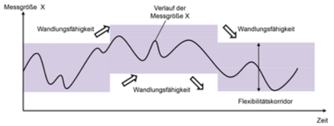
»Forecasts remain difficult, especially when it comes to the future«

E-Mobility

- Change in powertrain value creation
- New market participants
- Lightweight construction

Volatile markets and product portfolios





- Adaptable factories
- Return of manual processes, lean automation
- Data driven approaches + QM

Autonomous driving

- New E/E architectures
- New vehicle concepts
- New interior concepts

Shared mobility, mobility systems

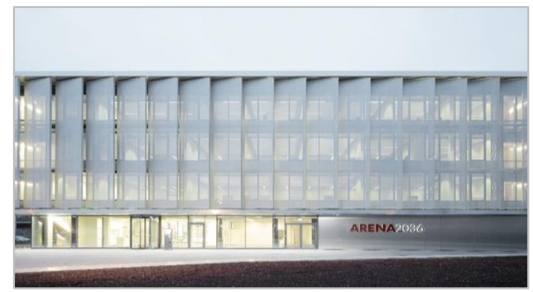
moovel

UBER

- New vehicle types
- Changed life cycle
- New business models

ARENA2036-Infrastructure

Flexible environment for the hardware-based knowledge work of the future



Key data:

- Construction time: 1 year
- Gross floor area: 10,000 m²
- Workplaces: 160
- Construction costs: approx. 30 Mio. € (Uni- and EU-funds)

Features:

- State-of-the-art building technology
- Transformable environment and adaptable infrastructure
- Modern, attractive and exemplary working environment for factory 4.0

Network and Partners

Leading technology partners from science and industry work together in ARENA2036

University partners and research institutes

Universität Stuttgart

- IPVS
- ISW
- IFB – Institut für Flugzeugbau / Institute of Aircraft Design
- iew – Institut für Elektrische Energiewandlung
- ITFT – Institut für Textiltechnik, Faserbasierte Werkstoffe und Textilmaschinenbau
- IKT – Kunststofftechnik Stuttgart
- IFT – Institut für Fördertechnik und Logistik
- IFSW – Universität Stuttgart, Institut für Strahlwerkzeuge, Stuttgart Laser Technologies
- BWT – Abteilung Berufs-, Wirtschafts- und Technikpädagogik
- INUE – Institut für Nachrichtenübertragung
- IPOC – Institut für Polymerchemie
- IVK – Institut für Verbrennungsmotoren und Kraftfahrwesen
- IAT – Institut Arbeitswissenschaft und Technologiemanagement
- iEH
- IfLA – Institut für Linguistik: Anglistik
- IFF – Institut für Industrielle Fertigung und Fabrikbetrieb
- IFKB – Institut für Fertigungstechnologie keramischer Bauteile
- IKTD – Institut für Konstruktionstechnik und technisches Design
- IMWF – Institut für Materialprüfung, Werkstoffkunde und Festigkeitslehre

Further partners:

- Hochschule der Medien
- Swinburne University of Technology
- Fraunhofer
- DITF – Deutsche Institute für Textil+Faserforschung
- FKFS
- DLR

Industry partners

- EWS Tool Technologies
- Daimler
- Festo
- csi
- AL Automotive Lighting
- Bär
- pilz
- Constellium
- KUKA
- Altair
- John Deere
- ThingOS
- Siemens
- Plug and Play
- Bosch
- Trumpf
- DSM – Bright Science. Brighter Living.
- Schunk
- BASF – We create chemistry
- Dyna More
- DXC.technology
- Faro
- Nokia
- Hewlett Packard Enterprise
- Balluff
- Spie

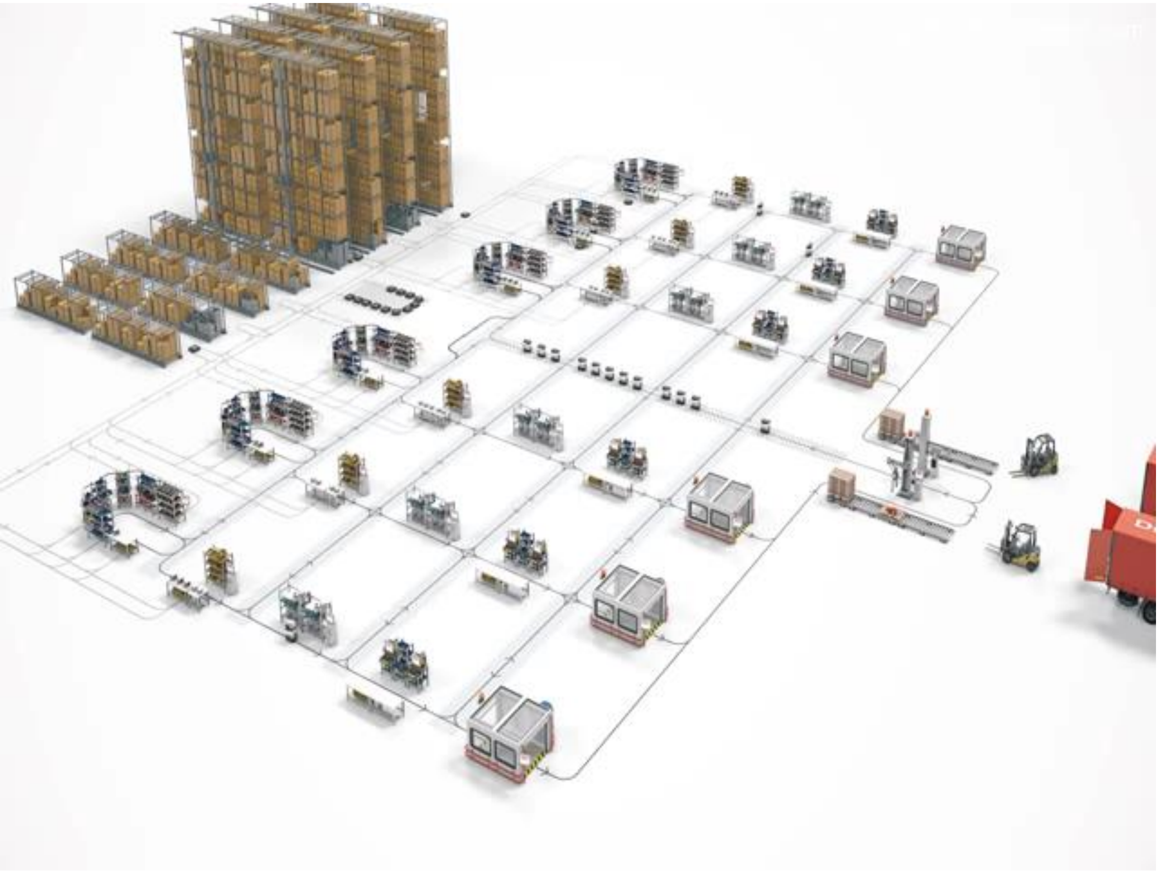
Example Kuka – flexible, versatile and highly automated body in white production

Robots replace people

source: Kuka

On the Way to Fluid Production

Example SEW Eurodrive – merging of fluid logistics and partially automated U-Shape value-added cells



source: SEW Eurodrive

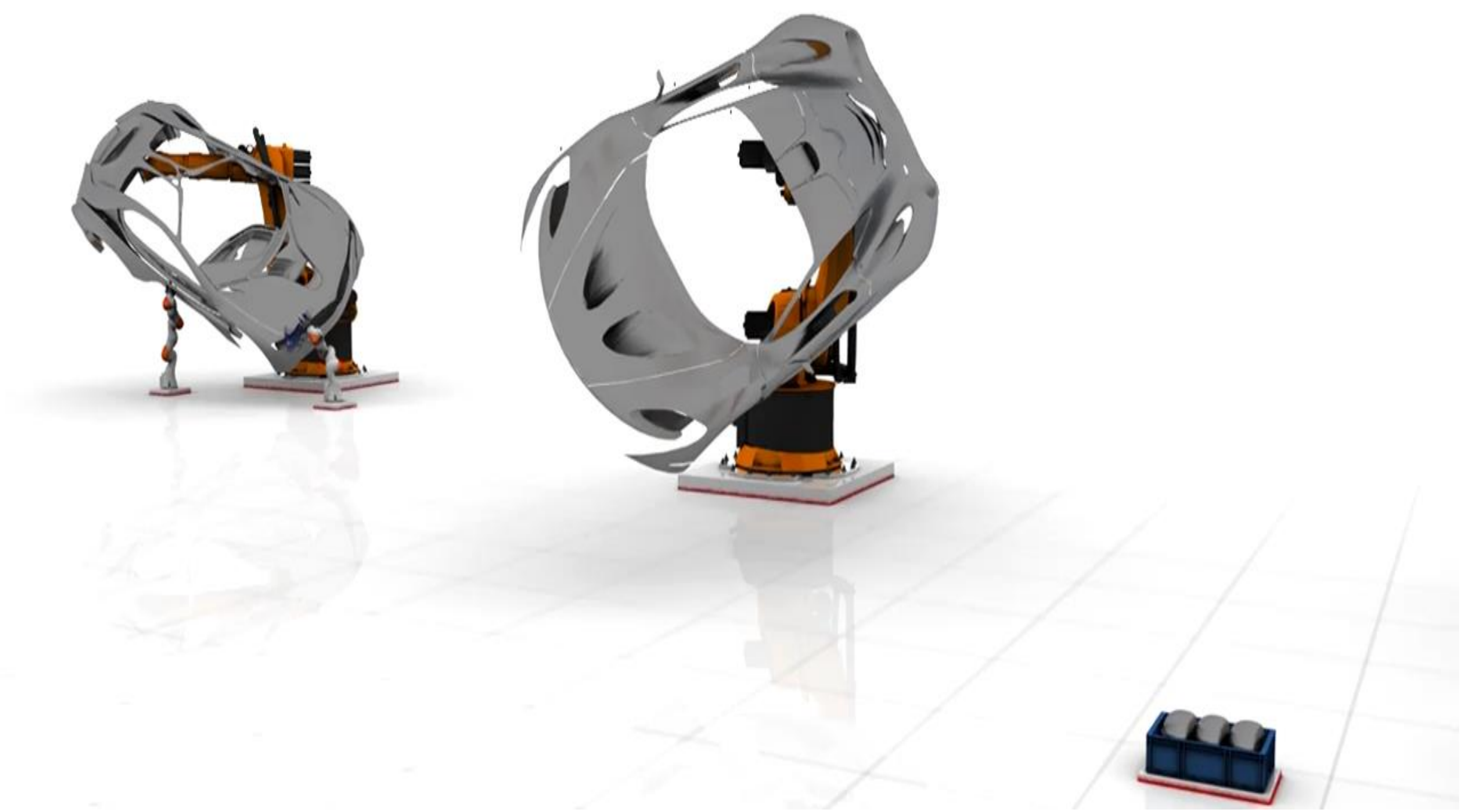
All Objects in a Factory will be mobile as far as Possible

Example: Audi R8 – freely navigating AGV (navigation as a service)

source: audi-mediaservices.com

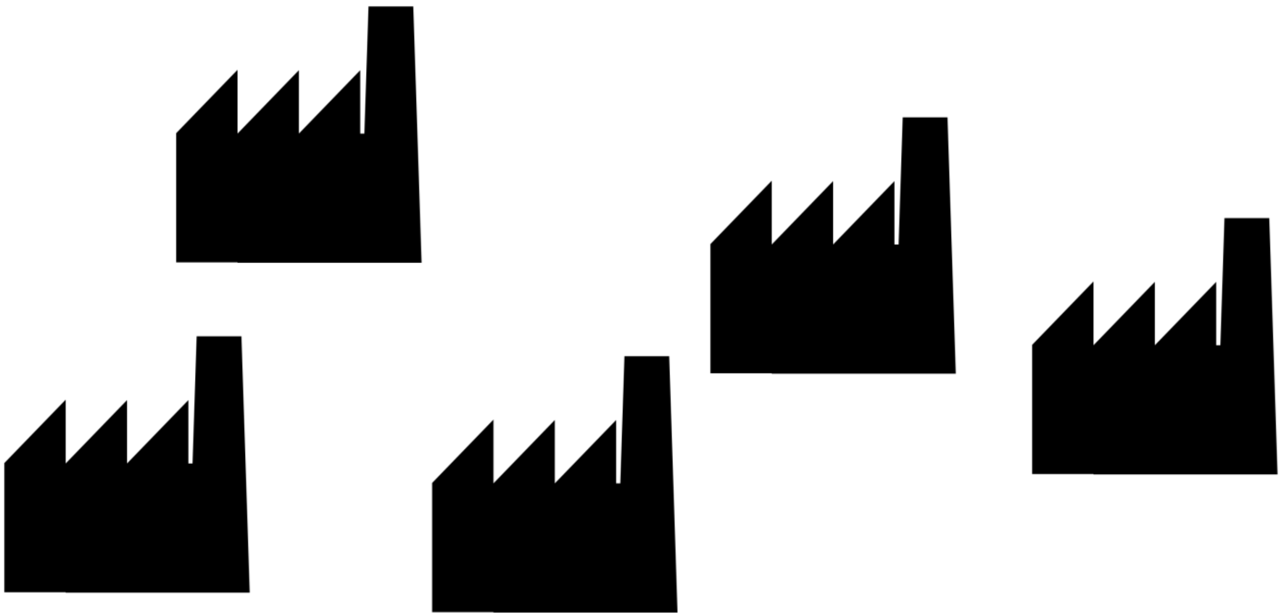
Fluid Production – Everything is Mobile and Scalable

Example: Active floor of Benjamin Logistics (start up company)



source: Benjamin Logistics

Detection of Anomalies: Machine benchmark
Direct comparison of time per task and per machine



Further information: https://www.ipa.fraunhofer.de/de/referenzprojekte/Fertigungssystemplanung-SCHOTT.html

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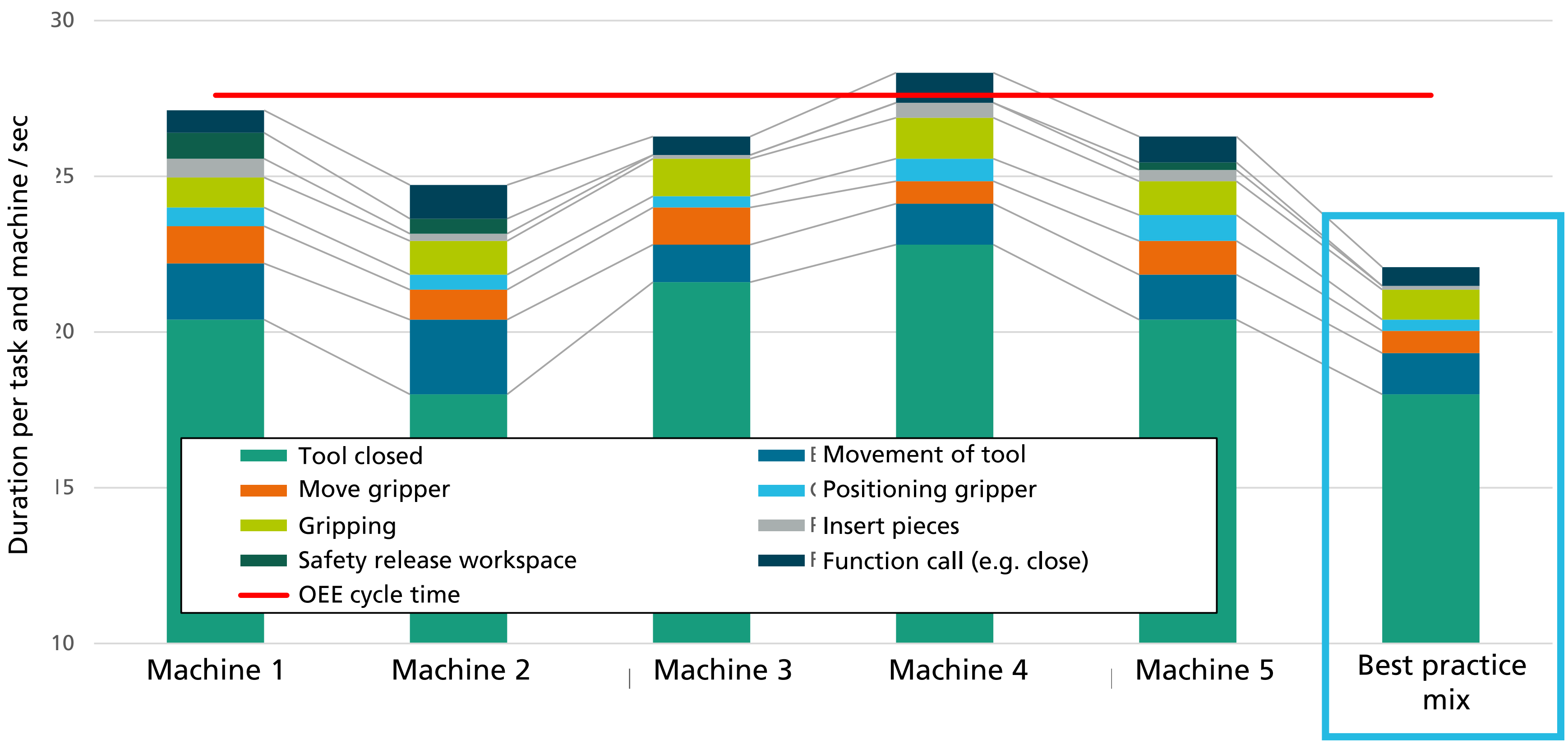
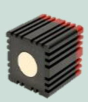
Direct comparison of time per task and per machine



source: Fraunhofer IPA

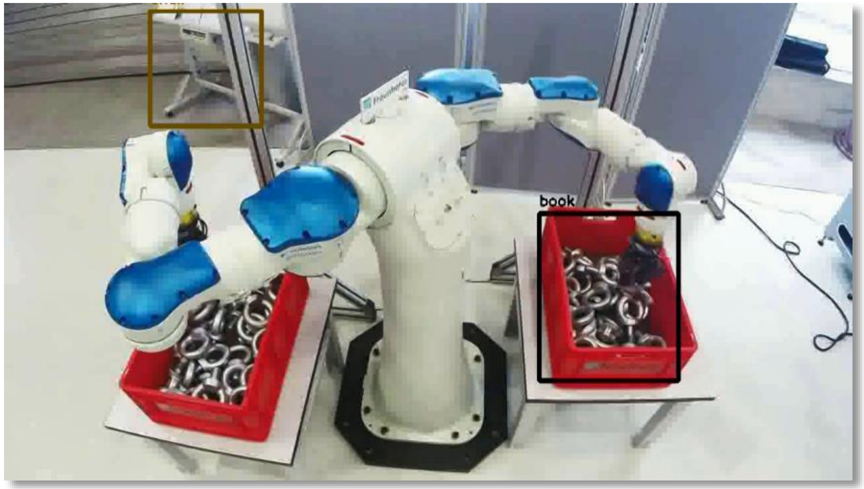
ML supported robotic Bin Picking
Example: Deep rasping

- Singularization of chaotically stored objects
- Object detection using 3D point cloud of the bin
- Reliable industrial solution, 20+ installations in production
- Deep Grasping: use of deep learning for bin picking→ faster computation, easier maintenance

Runtime measurement	Phase position measurement	Laser tri-angulation	Stereo vision
 MESA SR4000	 Sick LMS400	 Leuze LPS36	 Ensenso N10

source: Fraunhofer IPA, Werner Kraus; Video: https://www.youtube.com/watch?v=xhTkgajg8wQ

Deep Grasping
You only look once (YOLO)

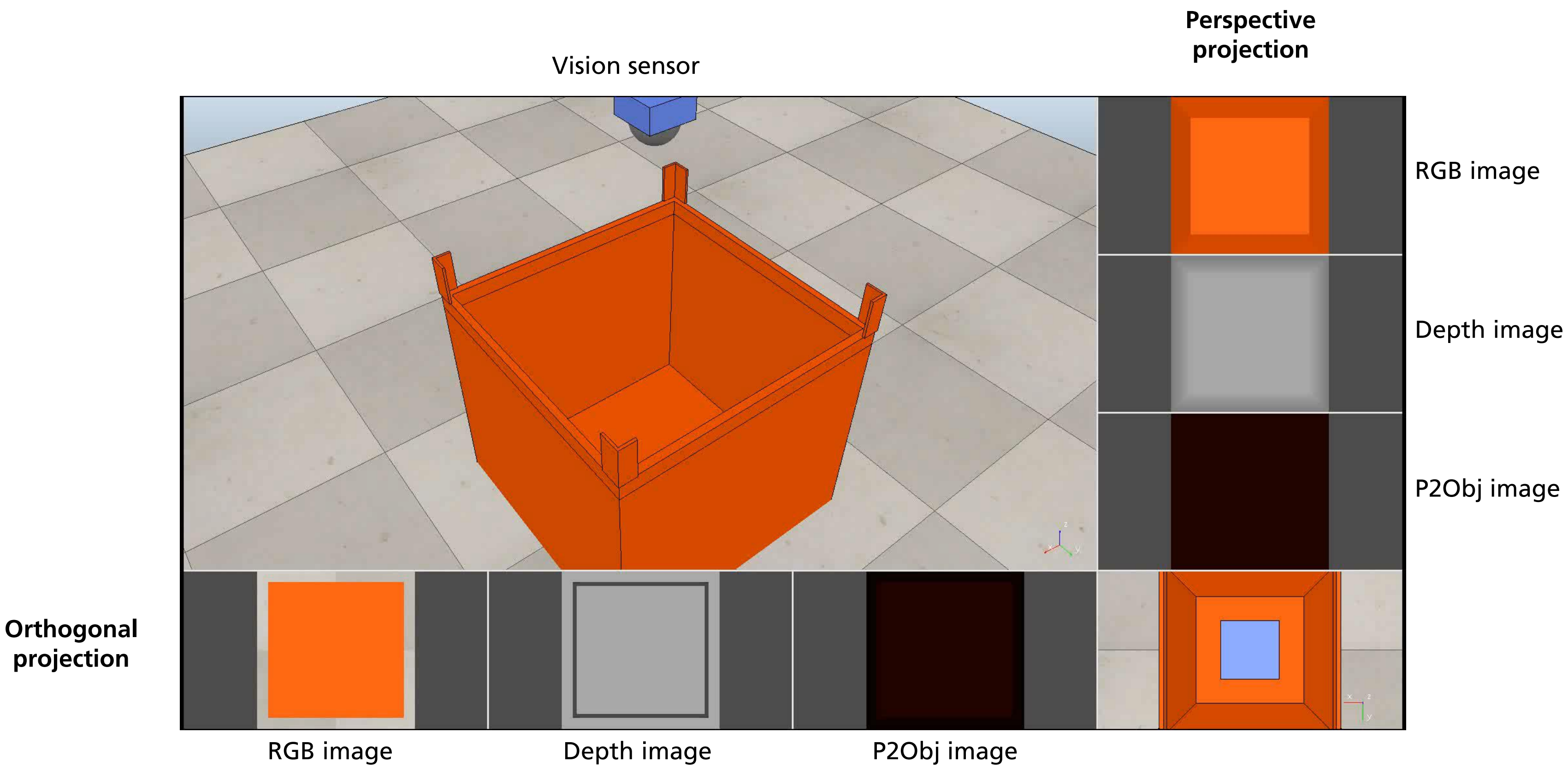


- You only look once (YOLO): Real-Time Object Detection
- Fine-tuning of the network is needed!

Video source: https://www.youtube.com/watch?v=xhTkgajg8wQ; https://www.youtube.com/watch?v=VOC3huqHrss

Deep Grasping

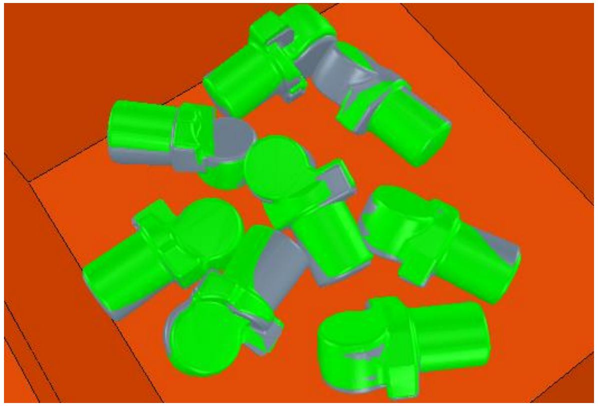
Data generation – Virtual learning environment (V-REP)

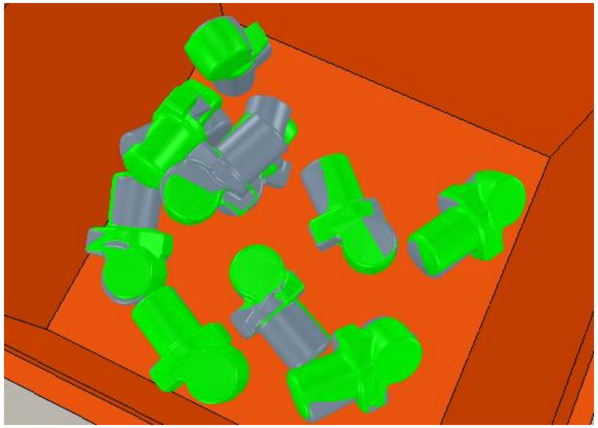


source: Fraunhofer IPA, Werner Kraus

Deep Grasping
3D Object Pose Estimation

- 3D Object Pose Estimation of work pieces with neural networks based on YOLO-Approach
- Input: Depth image
- Output: 3D-Pose
- Results: (grey: real pose; green: predicted pose)
- Advantages:
  - Objects can be detected using neural networks
  - Fast computation: Pose estimation with neural networks takes only around 10 ms/ point cloud compared to 1 s with traditional computer vision algorithms





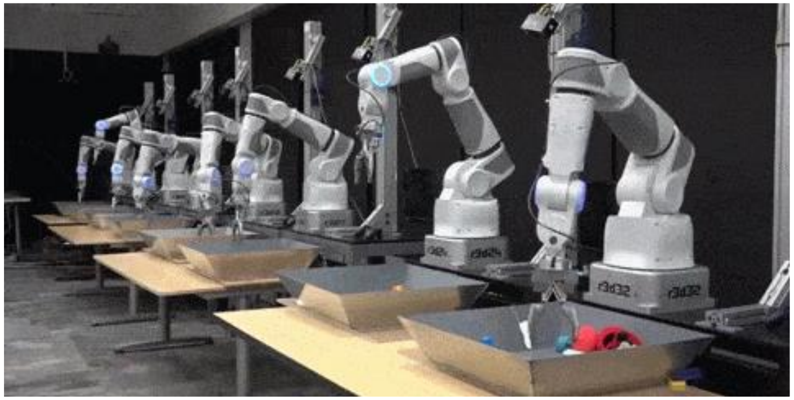
source: Fraunhofer IPA, Werner Kraus

»Bin Picking« as Use Case for Industrie 4.0

Cloud Picking

Hand-Eye-Coordination with Robots (Google)

- 14 robots learned simultaneously within ~800.000 pick attempts to grasp varied objects from a bin; a monocular camera is used
- several robots exchange their experiences
- also unknown objects are being picked, deviations of camera position are being compensated due to the robustness of the used algorithms



source: https://i.ytimg.com/vi/H4V6NZLNu-c/hqdefault.jpg

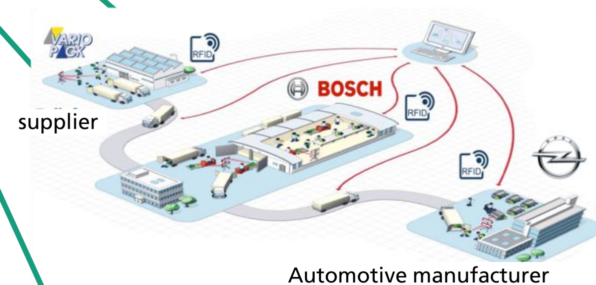
Business potential of Integrated Industry (Industrie 4.0)

Specialists expect an increase in overall performance between 30 to 50 % in value creation

Estimation of potential benefits

Costs	Effects	Potential
Stock costs	▪ Reduction of safety stocks ▪ Avoiding Bullwhip and Burbidge effects	**-30 to -40 %**
Manufacturing costs	▪ Improving of OEE ▪ Process control loops ▪ Improvement of vertical and horizontal staff flexibility ▪ Use of Smart Wearables	**-10 to -30 %**
Logistic costs	▪ Higher level of automation (milk run, picking etc.) ▪ Smart Wearables	**-10 to -30 %**
Complexity costs	▪ Wider span of supervision ▪ Reduced trouble shooting ▪ Prosumer model ▪ Everything as a Service (XaaS)	**-60 to -70 %**
Quality costs	▪ Near-realtime quality control loops	**-10 to -20 %**
Maintenance costs	▪ Optimization of stock levels ▪ State-oriented maintenance (process data, measurement data) ▪ Dynamic priorization	**-20 to -30 %**

Pilot project at Bosch: Restructuring of complete distribution process based on an in-plant logistics center in an Industrie 4.0 project.



-10 % milkruns

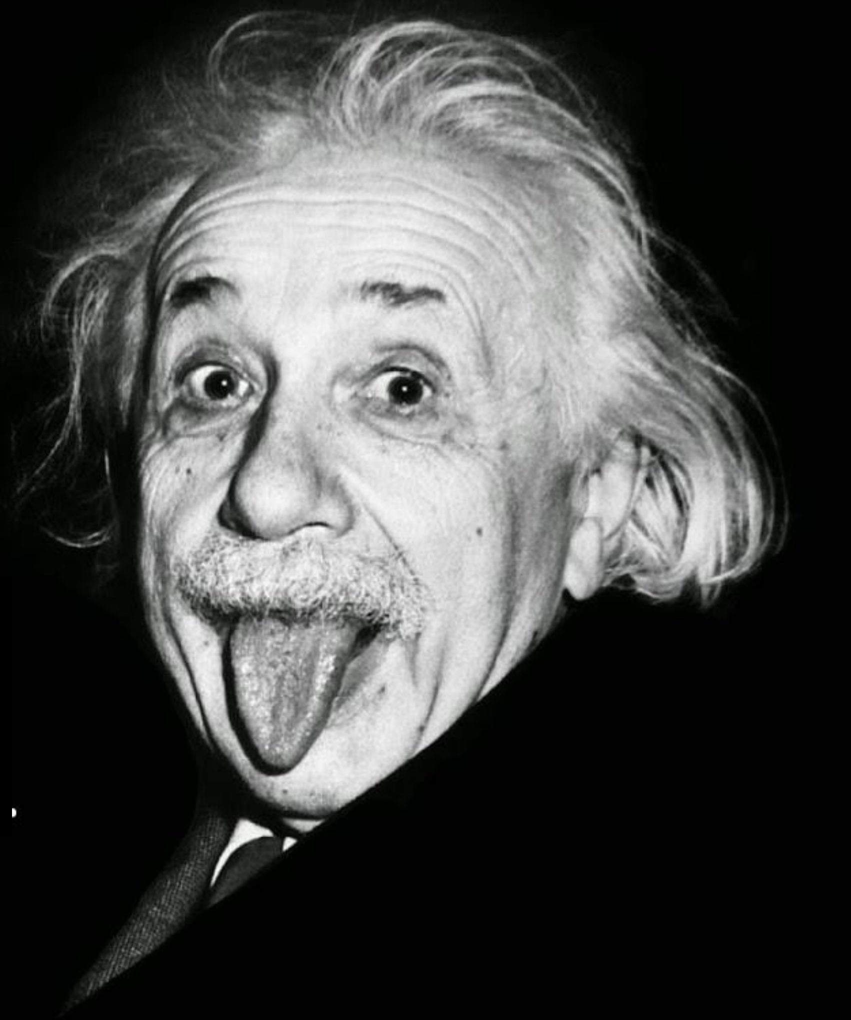
+10 % produc-tivity

-30 % stock reduction

source: IPA/Bauernhansl, Bosch

The definition of insanity is
doing the same thing over and over
again and expecting different results.

Albert Einstein



Successful Introduction of Industrie 4.0

- Challenges and Requirements for ICT
- Best Practices
- Outlook on the Future

ISBN 978-3-658-04681-1

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