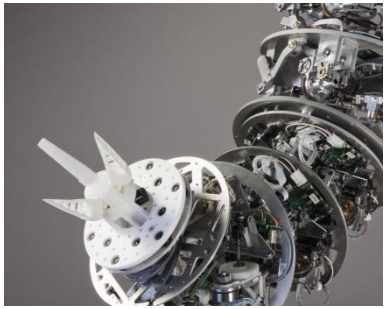
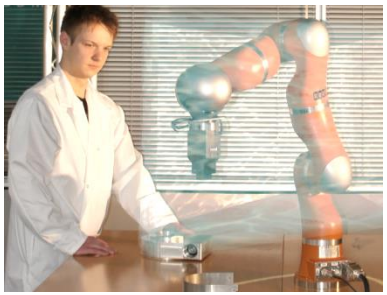
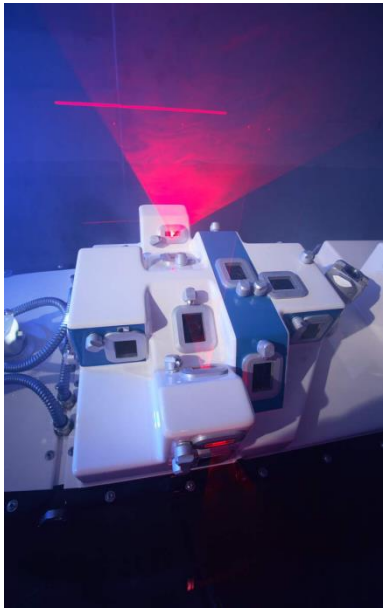
Collaborative Robotics in Industry 4.0

What's hot right now and where is it heading?

THA Webinar 05.10.2017







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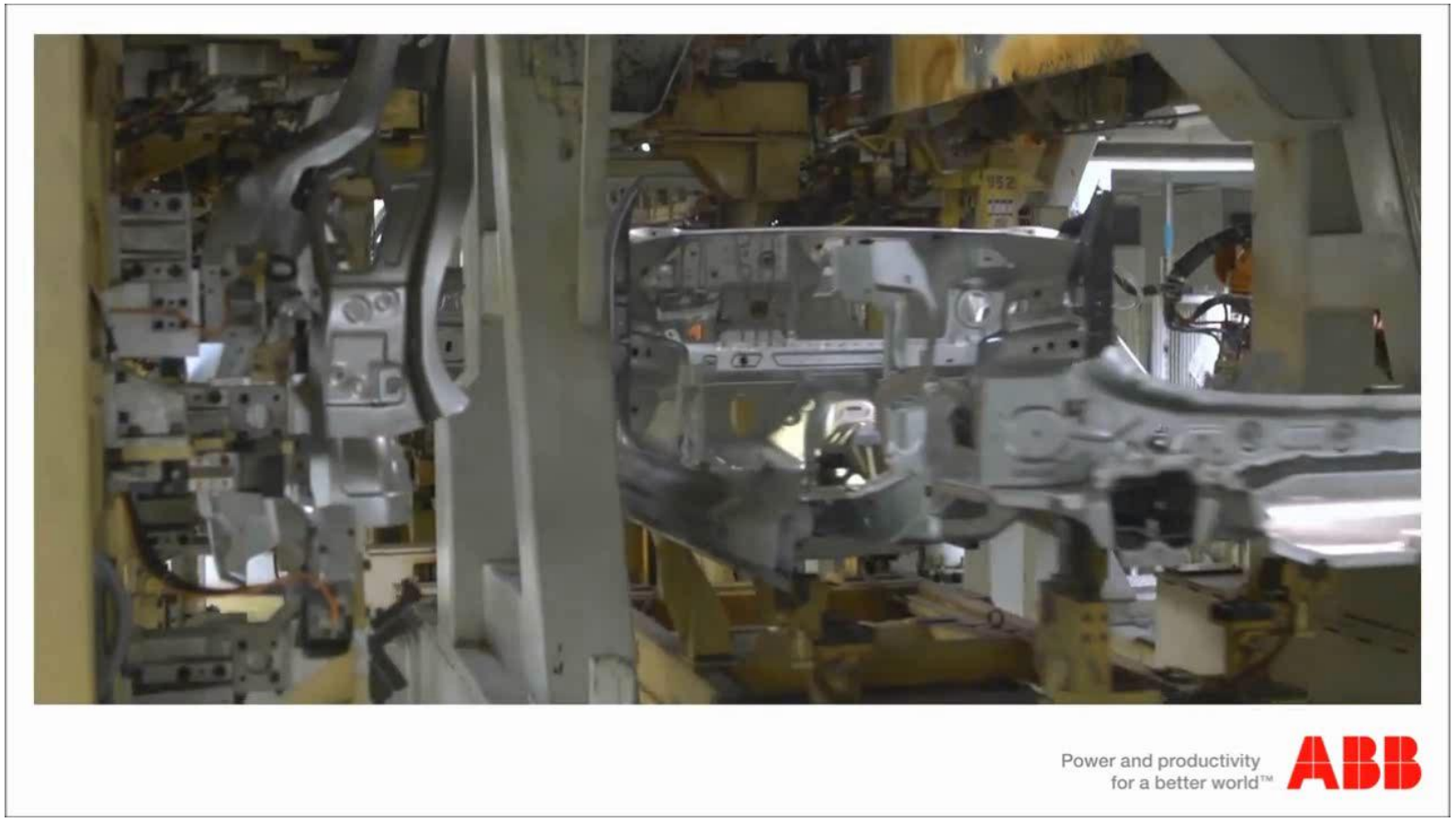
Collaborative Robotics in Industry 4.0

Overview

- What is Human-Robot Collaboration?
  - Common misconceptions
- Overview state of the art for collaborative robots
- Vision for Robotics in Industry 4.0
- Example of mobile assistance system using Industry 4.0 techniques
- Outlook – what's next?

Human-Robot Collaboration

What is HRC?



http://www.youtube.com/watch?v=ArxzMqf3aZg

Human-Robot Collaboration

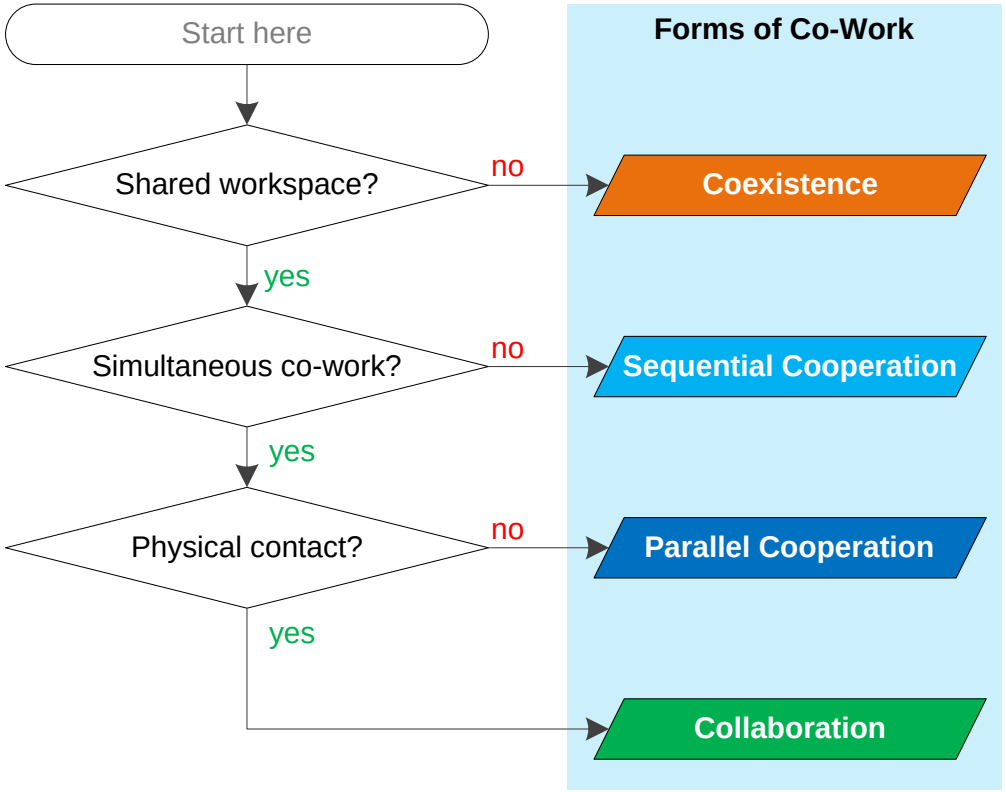
What is HRC?

DIN EN ISO 10218-1:2011

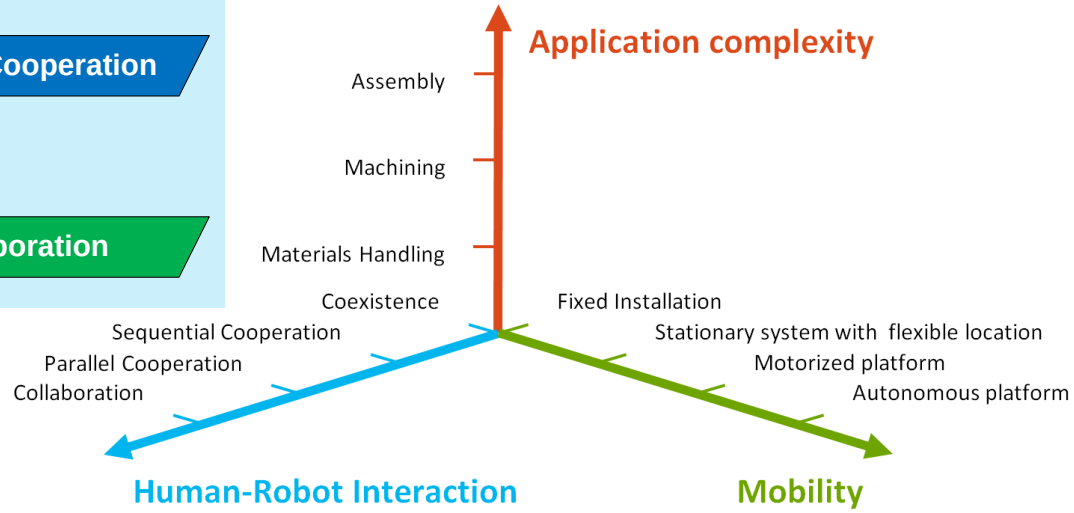
- Collaborative Operation:
  - State in which purposely designed robots work in direct cooperation with a human within a defined workspace

Human-Robot Collaboration

Classification



Behrens, R.; Saenz, J.; Vogel, C.; Elkmann, N.: "Upcoming Technologies and Fundamentals for Safeguarding All Forms of Human-Robot Collaboration", 8th International Conference Safety of Industrial Automated Systems (SIAS 2015), Königswinter, Germany 18-20 November, 2015. ISBN 987-3-86423-163-6, S.18-23



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Human-Robot Collaboration

Why?

- Because everyone's doing it
- The bottom line
  - Higher productivity
  - Higher quality
- Ergonomics
  - Ageing workforce
- Maintaining production in high-wage countries close to design and engineering centers

Human-Robot Collaboration

HRC Misconception

- “HRC is just like regular robotics, just without a fence”

Human-Robot Collaboration

HRC Misconception

- “HRC is just like regular robotics, just without a fence”

http://www.youtube.com/watch?v=ArxzMqf3aZg

Human-Robot Collaboration

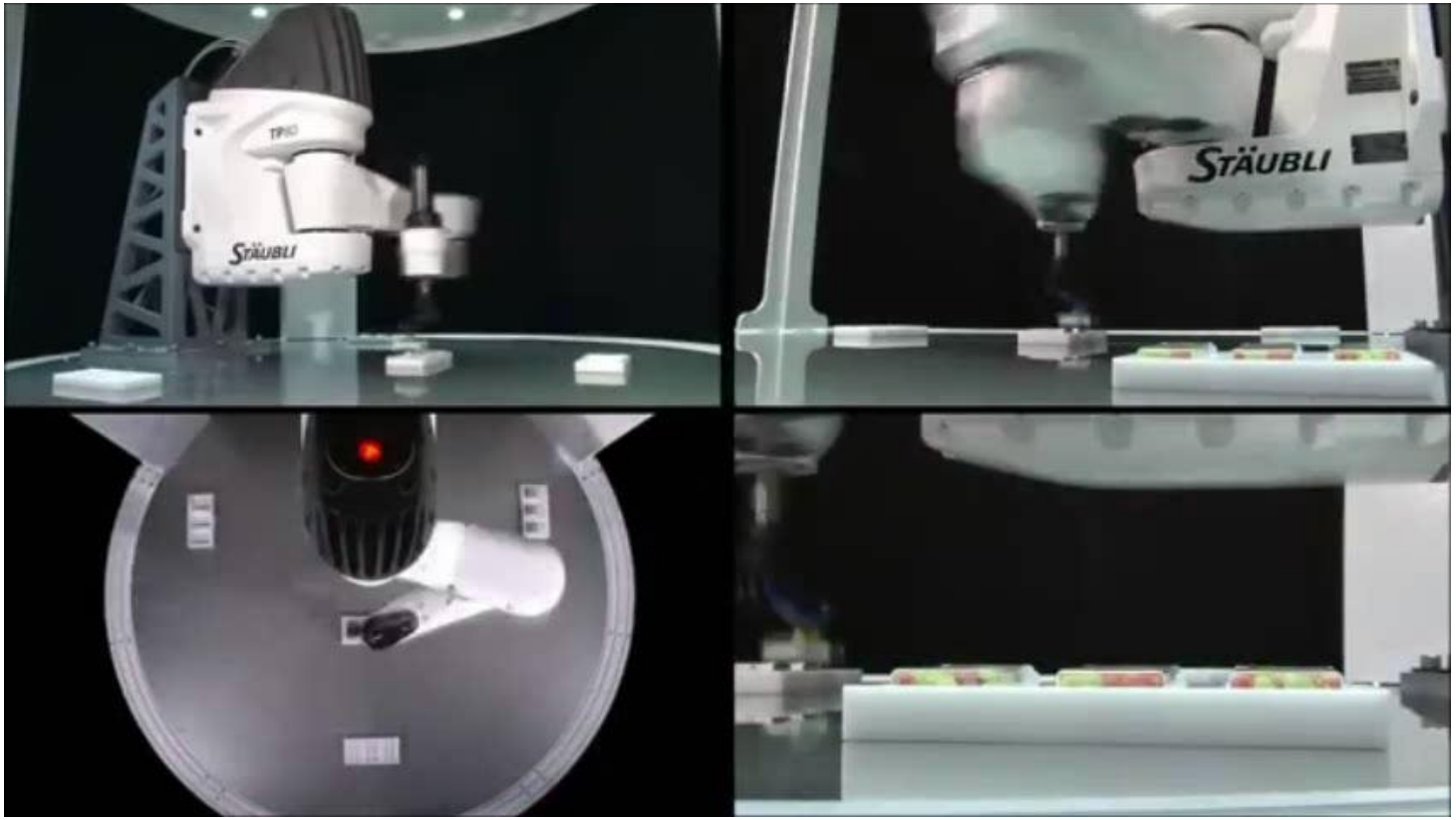
HRC Misconception

- “Robots should still be able to move as fast as they do now with fences”

Human-Robot Collaboration

HRC Misconception

- "Robots should still be able to move as fast as they do now with fences"



http://www.youtube.com/watch?v=Em7C1SlqId8

Human-Robot Collaboration

HRC Misconception

- “Only the new generation of lightweight robots are suitable for HRC”

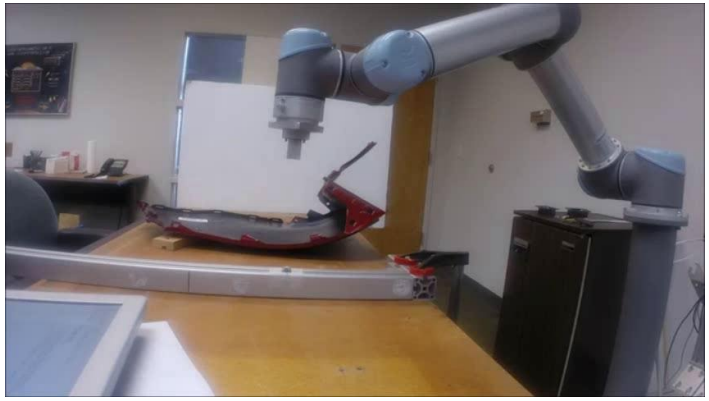
Human-Robot Collaboration

HRC Misconception

- "Only the new generation of lightweight robots are suitable for HRC"

Universal Robot

https://www.youtube.com/watch?v=7vdGcxghbeQ



https://www.youtube.com/watch?v=7-q6U8NNaRs

KUKA iiwa

https://www.youtube.com/watch?v=J71JNUUd7O8

Gomtec Roberta

Human-Robot Collaboration

HRC Misconception

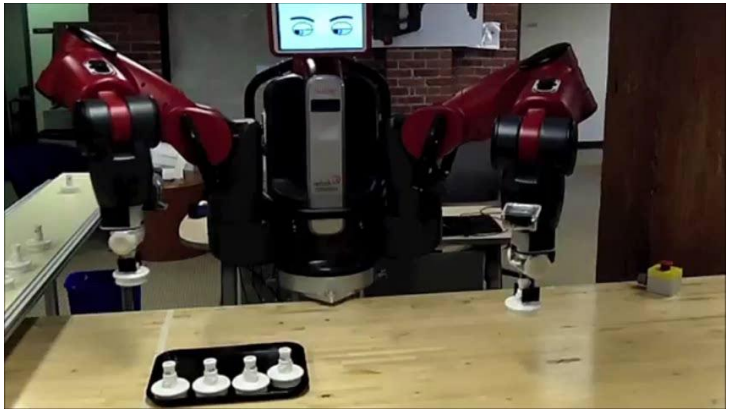
- "Only the new generation of lightweight robots are suitable for HRC"

ABB yumi

https://www.youtube.com/watch?v=uuZ_Ov5rMUw

https://www.youtube.com/watch?v=gXOkWuSCkRI

Baxter



https://www.youtube.com/watch?v=ke8yFtr9FAE

Nextstage Kawada

Human-Robot Collaboration
HRC Misconception

- "Only the new generation of lightweight robots are suitable for HRC"

Exemplary application from Adam Opel AG for mounting door in final assembly area with HRC

State of the art of Collaborative Robotics

Where are we right now?

Key enabling technologies

- Robots with safe control systems
  - New programming paradigms (offline, teach-in, skills-based)
- New safety sensors
  - Able to communicate with robot
  - Allow system to react to environment, people
- Standards and regulations
  - Testing and validation methods

State of the art of Collaborative Robotics

Where are we right now?

Machinery Directive	
ISO 12100, Parts 1 / 2	Safety of Machinery Terms and definitions, general principles for design
ISO 14121 (EN 1050)	Safety of Machinery Principles for risk assessment
EN ISO 10218 Part 1 / Part 2	Safety Requirements for Industrial Robots: "Robots" (Part 1) and "Robot Systems and Integration" (Part 2)
ISO/TS 15066	Robots and robotic devices - Collaborative robots Safety requirements (supplements EN ISO 10218 Part 2)
ISO 13849, Parts 1 / 2	Safety of Machinery Safety-related parts of control systems
ISO 13855	Safety of Machinery Positioning of safeguards with respect to the approach speeds of parts of the human body
IEC/TR 61496-4	Safety of Machinery - Electro-sensitive protective equipment - Part 4: Particular requirements for equipment using vision-based protective devices
DIN EN 61508	Functional Safety of safety-relevant electric, electronic and programmable electronic systems

State of the art of Collaborative Robotics

Where are we right now?

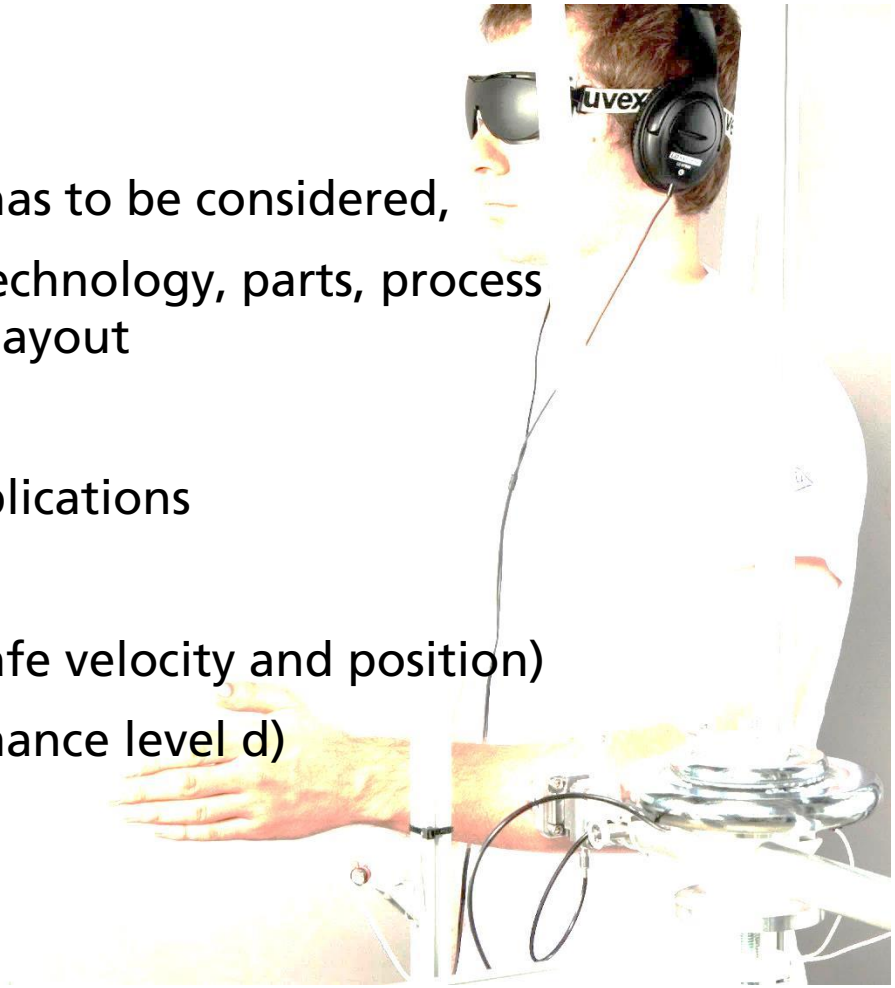
Safety concepts according to DIN EN ISO 10218 and ISO/TS15066

- **DIN EN ISO 10218** and **ISO/TS15066**:
  4 concepts for designing HRC workplaces
  - Safety-rated monitored stop
  - Hand guiding
  - Speed and separation monitoring
  - Power and force limitation

State of the art of Collaborative Robotics

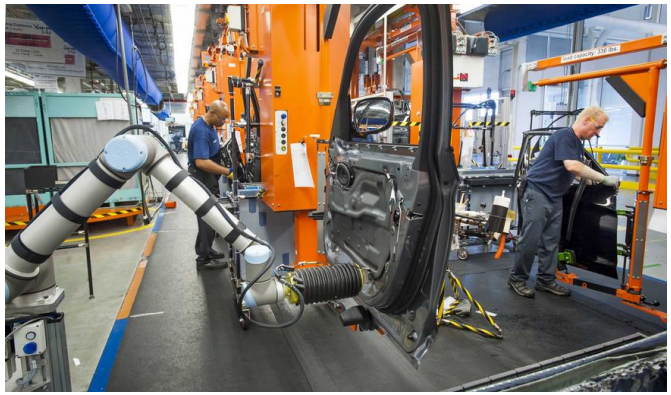
Where are we right now?

- A risk assessment is mandatory
  - The entire cell and application has to be considered,
    - Robot, tensioner, gripping technology, parts, process parameters, sensors, system layout
  - "*The*" safe robot does not exist
  - No *one* safety sensor for all applications
- General hardware requirements:
  - safety-certified robot control (safe velocity and position)
  - safety-certified sensors (performance level d)



State of the art of Collaborative Robotics

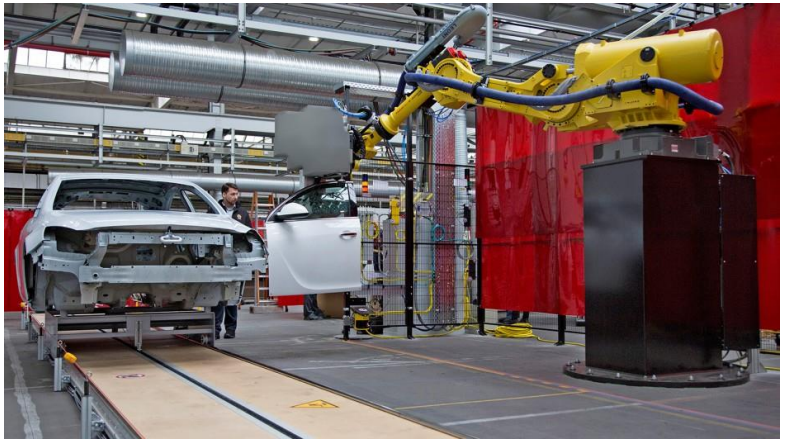
Industrial examples



https://www.press.bmwgroup.com/deutschland/article/detail/T0209722DE/neuartige-mensch-roboter-zusammenarbeit-in-der-bmw-group-produktion?language=de

https://www.roboticsbusinessreview.com/manufacturing/universal_robots_ur5_goes_to_work_for_volkswagen/

http://www.computer-automation.de/feldebene/robotik/artikel/119127/



https://opelpost.com/03/2016/kollege-roboter/

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State of the art of Collaborative Robotics

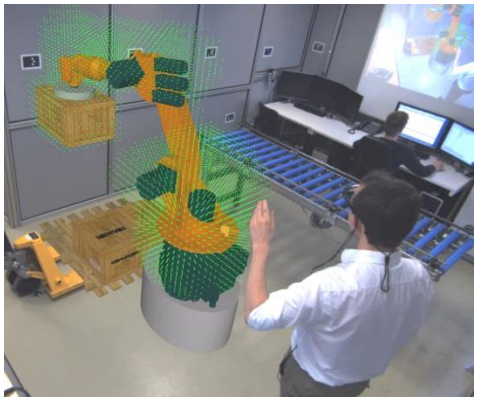
New technologies

Tactile and capacitive sensor systems

- Tactile sensors on robots or machines
- Proximity detection (capacitive sensors)
- Pressure-sensitive floor mats with spatial resolution

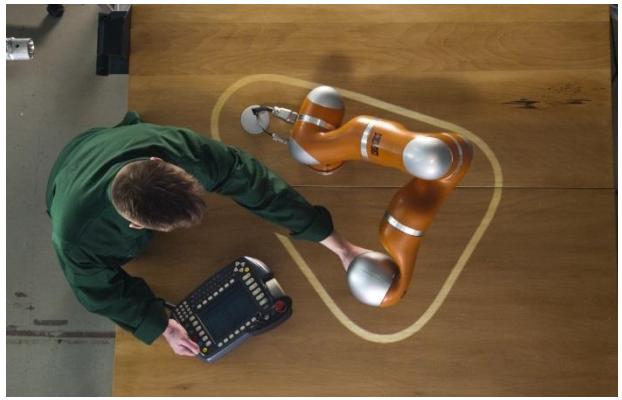
Planning, Set-up and Testing

- Collision measurement
- Augmented-Reality environment
- Planning of HRI cells



Sensor-based Workplace Monitoring

- Projection and camera based systems
- Online planning of safeguarded zones
- Dynamic safe area planning
- Safeguarding tools



New enabling technologies

Tactile sensor systems

- Geometrically adapted tactile sensors with shock-absorbing characteristics for safe collision detection

→ Collision detection and tactile interaction

https://youtu.be/TwOFHZfpv3w

https://youtu.be/5bUtGeaQRVk

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New enabling technologies

Pressure-sensitive Flooring combined with Projectors

Safe Human-Robot Cooperation with high payload robots in industrial applications

- SAPARO -

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pilz the spirit of safety

http://www.iff.fraunhofer.de/en/business-units/robotic-systems/saparo.html

ECHORD++

grant agreement no. 601116

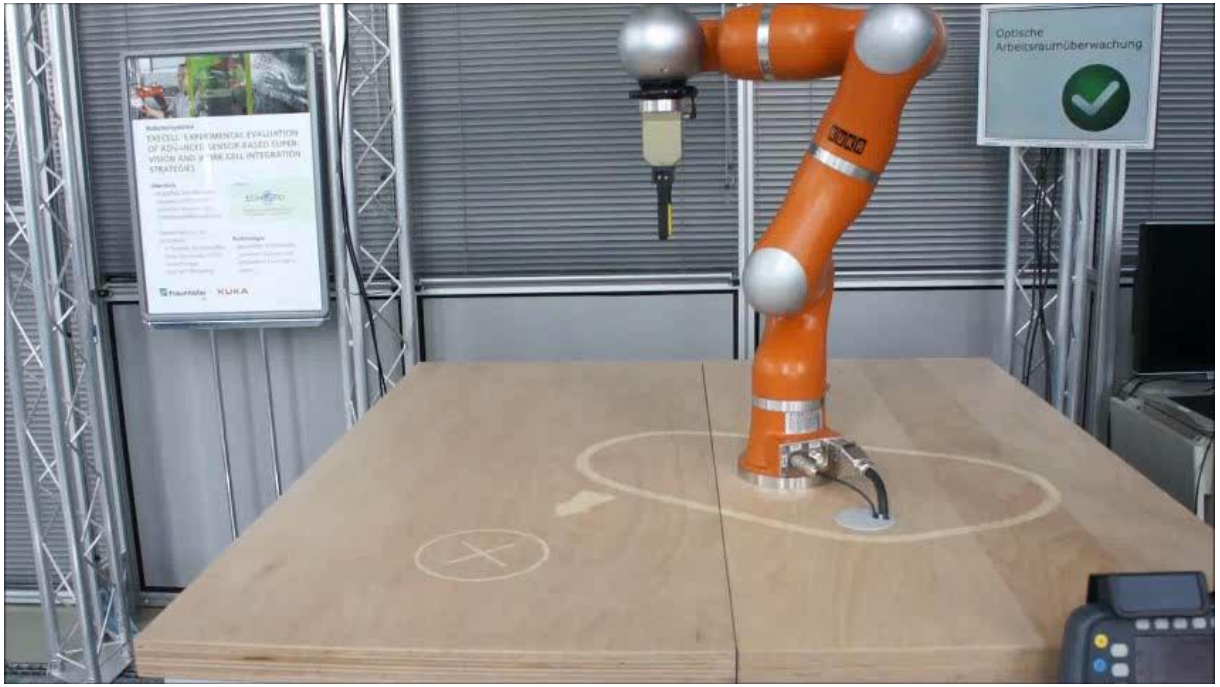
https://youtu.be/sykfaMuuVEI

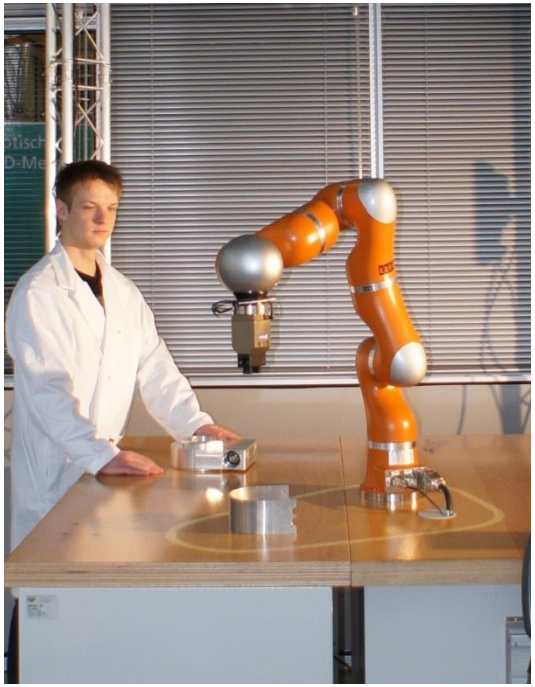
New enabling technologies

Sensor-based workspace monitoring

- Projection- and camera-based safety system for workspace monitoring with dynamic safety zones

→ Combination of hard and soft safety





https://youtu.be/wxDF_EFpLlY

KUKA

European Clearing House for Open Robotics Development
www.echord.info

ECHORD

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New enabling technologies

Sensor-based workspace monitoring

https://youtu.be/tmLiWmVPFM4

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State of the art of collaborative robotics

Where are we right now?

Summary state of the art

- Big players testing the waters
  - Long development times
  - Grass blade approach

- No widespread adoption in sight
  - Toolboxes not in place
  - Technology only starting to catch up
  - Certification a big issue!!

Vision for Robotics in Industry 4.0

The robotics perspective

Robotics for Manufacturing

- Flexibility
  - Small lot sizes
  - Opening up new industries
- New programming paradigms
- Systems Engineering tools for improved design, validation of system

Vision for Robotics in Industry 4.0

Trends coming together

- Reference Architecture Model (RAMI 4.0)
  - Combining views over life cycle, hierarchy levels
  - Systems engineering efforts in robotics need to consider this view
- 5G Networks
  - Decentralized robot control systems (with communication latency < 1ms)

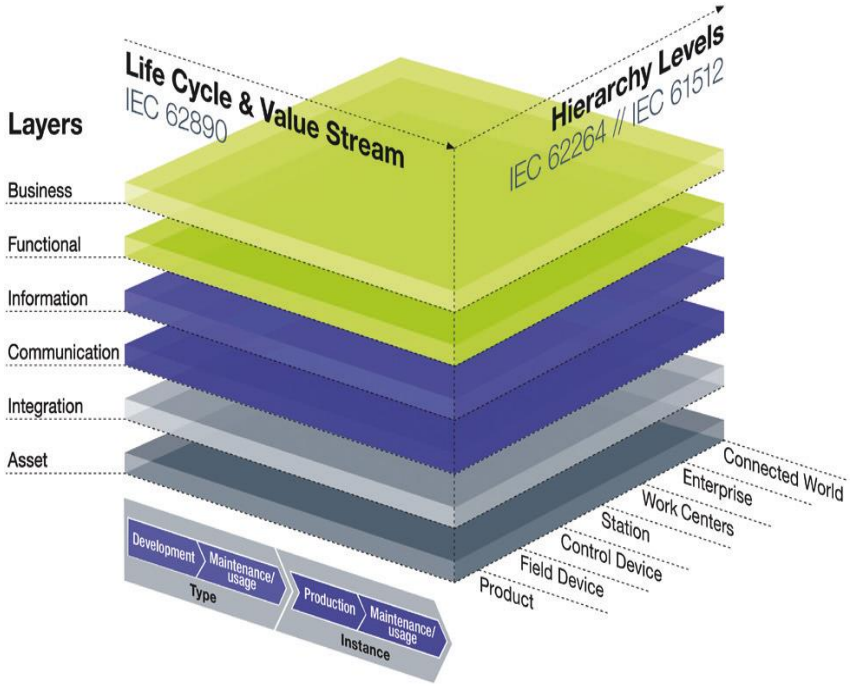

Image: Reference Architecture Model Industry 4.0 (RAMI 4.0)

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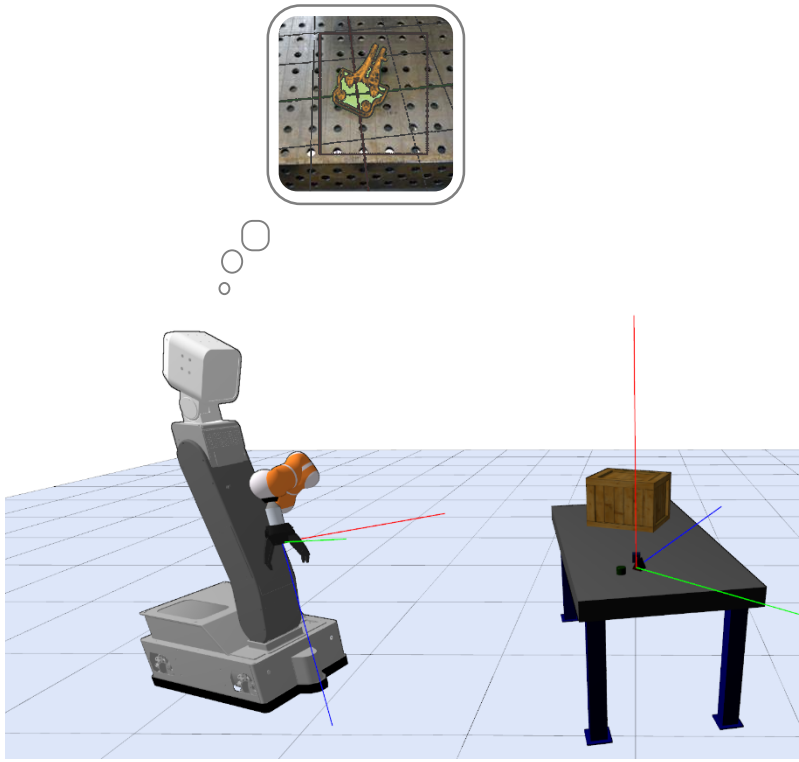
Vision for Robotics in Industry 4.0

Convergence of Industry 4.0 and Robotics

- Using the digital twin
  - Supporting faster programming through use of semantic data
  - Validating system prior to use with simulation and other tools
- Using novel safety sensors to allow for collaboration and shared workspaces
- Using sensors with higher resolution to better understand environment, react to inaccuracies in real world



Example of to mobile assistance system using Industry 4.0 techniques

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Vision for Robotics in Industry 4.0
Conclusion

- Collaborative robotics an integral part of Industry 4.0
- Digital Thread the key to new applications, higher flexibility (delivering on promises)
- Better methods for ensuring safety, certification needed to get past “Grass Blade“ approach

Vision for Robotics in Industry 4.0

Triple Helix outlook – final recommendations

Government

Support larger scale activities

Support roadmapping activities (e.g. PPP Robotics)

Ensure humans in focus of funded research!

Academia

Focus on big picture, look beyond single system

Research implications of human-centered production shift

Develop tools for design, pro-gramming

Industry

Support industry standards (e.g. RAMI 4.0)

Go beyond „Grass blade“ approach

Fraunhofer Institute for Factory Operation and Automation IFF
Sandtorstrasse 22
39106 Magdeburg

Contact

José Saenz
Robotic Systems Business Unit
Phone +49 391 4090-227
Fax +49 391 4090-93-227
email jose.saenz@iff.fraunhofer.de

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