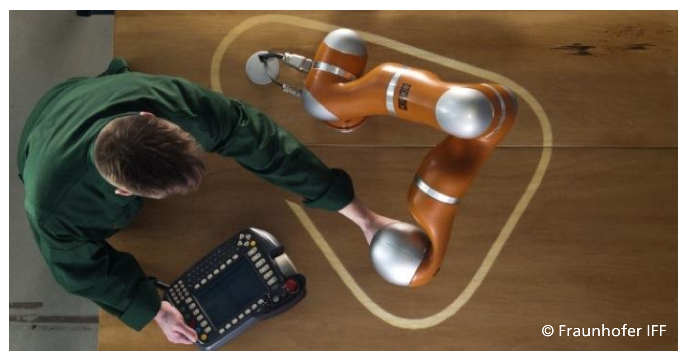
Computer-Aided Safety and Risk Prevention – *Pushing collaborative robotics from isolated pilots to large scale deployment*

INRS, Nancy, France
J. Saenz, C. Vogel, R. Behrens, E. Schulenburg, C. Walter, N. Elkmann 30.03.2017



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Overview of Presentation

- Introduction
- State of the art for design and implementation of collaborative robotics applications
    - Barriers to widespread use
- Challenging safety aspects
- Example of planning tools
- Our vision for Computer-Aided Safety (CAS)
- Implications of new approach

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Challenges, Motivation

Challenges

- Demographic change
- Lack of skilled personnel
- Production in high-wage countries
- Cost effectiveness
- Quality improvement
- New production concepts

Motivation

- Relief for humans of physical strain
- Flexible automation
- Merging of human and robot strengths
- Increase in efficiency, productivity and quality
- New facility concepts through omission of separating protective barriers

Capacitive sensors for proximity detection

Worker assistant with high-payload industrial robots
Manually guided robot/ safety/ ergonomics

Research priorities of the Fraunhofer IFF

- Stationary and mobile assistance robots
- Development of new technologies for safe human-robot collaboration
- Intuitive human-robot interaction
- Intelligent robot systems

Tactile sensors for collision detection

Mobile assistance robot „ANNIE“

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SoA - HRC door assembly, Adam Opel AG

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SoA - HRC door assembly, Adam Opel AG

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SoA - HRC hatchback interior paneling, Volkswagen AG

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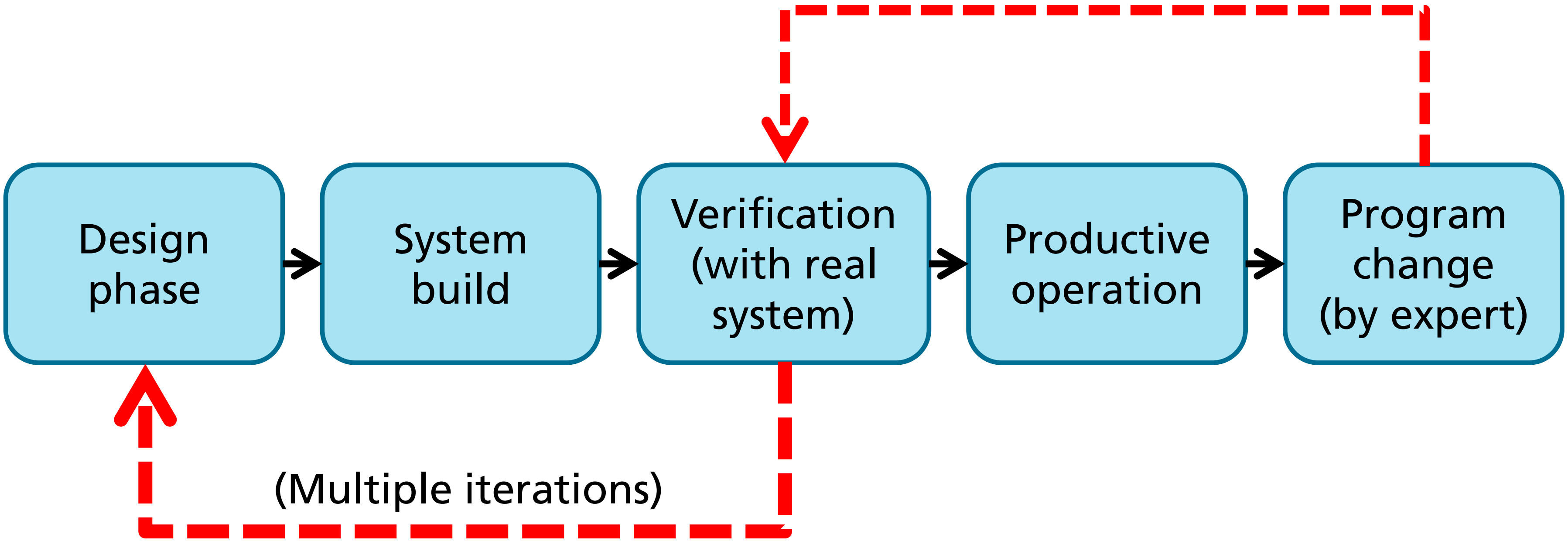
State of the art - design and implementation of applications



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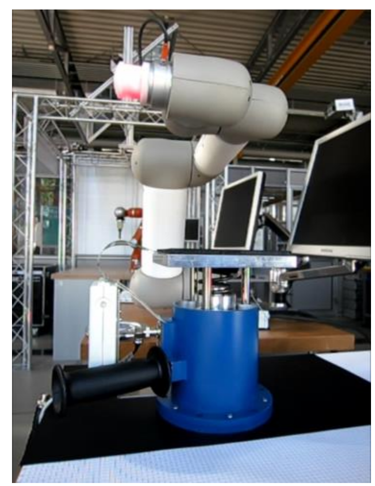
State of the art - design and implementation of applications

Design phase → System build → Verification (with real system) → Productive operation → Program change (by expert)

(Multiple iterations)



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State of the art - design and implementation of applications

Design phase

KUKA LBR iiwa

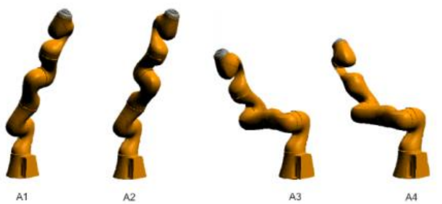

Fig. 4-8: 33% extension, axis 1 - axis 4

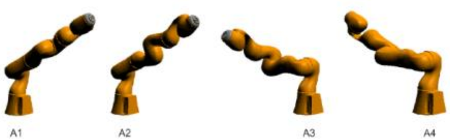

Fig. 4-9: 66% extension, axis 1 - axis 4

Fig. 4-10: 100% extension, axis 1 - axis 4

4.5.3 Stopping distances and stopping times for LBR iiwa 7 R800

4.5.3.1 Stopping distances and stopping times for STOP 0, axis 1 to axis 4

The table shows the stopping distances and stopping times after a STOP 0 (category 0 stop) is triggered. The values refer to the following configuration:

- Extension l = 100%
- Program override POV = 100%
- Mass m = maximum load (rated load + supplementary load on arm)

	Stopping distance (°)	Stopping time (s)
Axis 1	5.193	0.182
Axis 2	5.092	0.212

KUKA LBR iiwa

4.5.3.2 Stopping distances and stopping times for STOP 1, axis 1

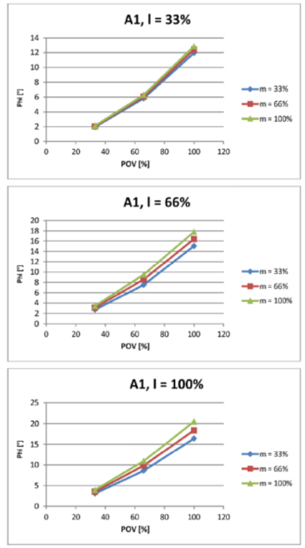

Fig. 4-11: Stopping distances for STOP 1, axis 1

4 Technical data KUKA

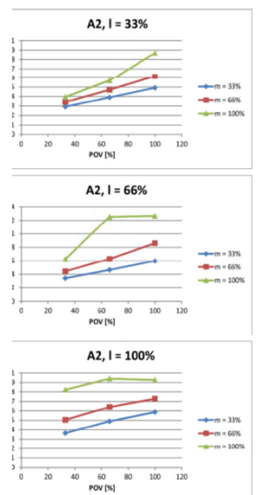

Fig. 4-14: Stopping times for STOP 1, axis 2

...nd stopping times for STOP 1, axis 3

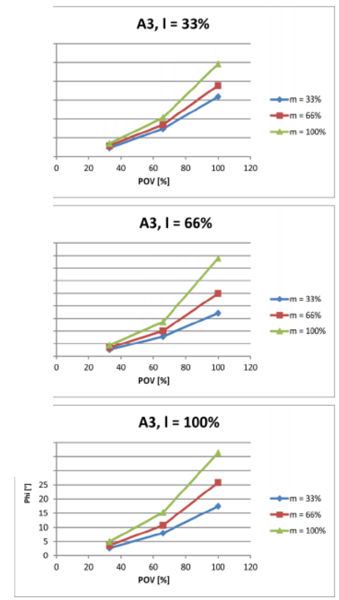

Fig. 4-15: Stopping distances for STOP 1, axis 3

...ances and stopping times for STOP 1, axis 4

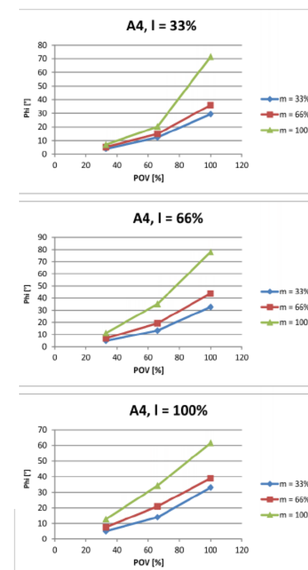

Fig. 4-17: Stopping distances for STOP 1, axis 4

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Challenging safety aspects

- Incomplete information for analyzing robot motion (low granularity)
  - Robot braking distances
  - Reaction times
  - Collision forces
  - Complex interdependencies (payload, configuration, speed)
- Verification
  - Iterative process
  - Physical system needed (capital outlay)
  - Outcome unclear
  - Required after every program change

→ **Economic uncertainty, low flexibility**

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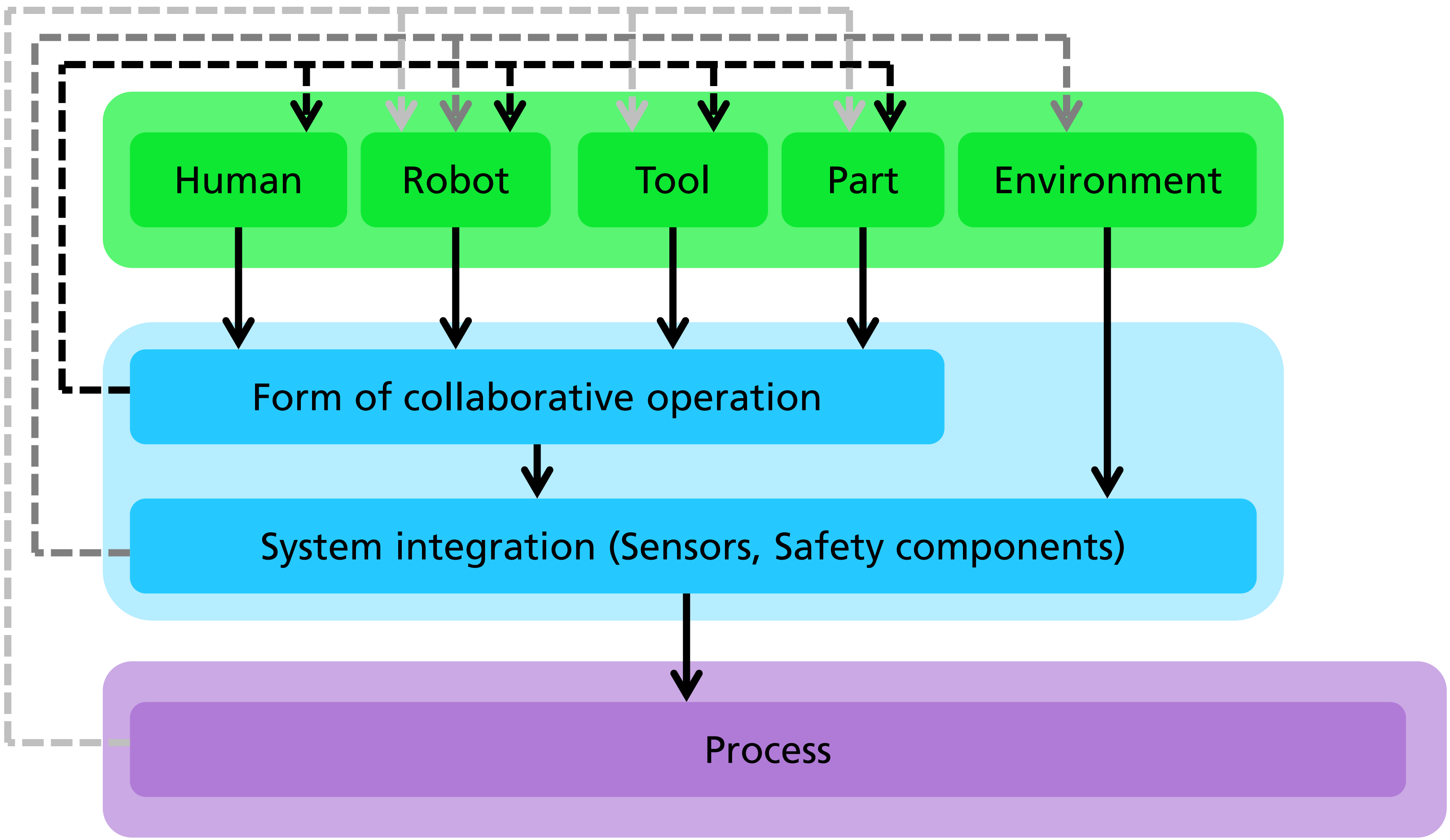
Challenging safety aspects

- System complexity



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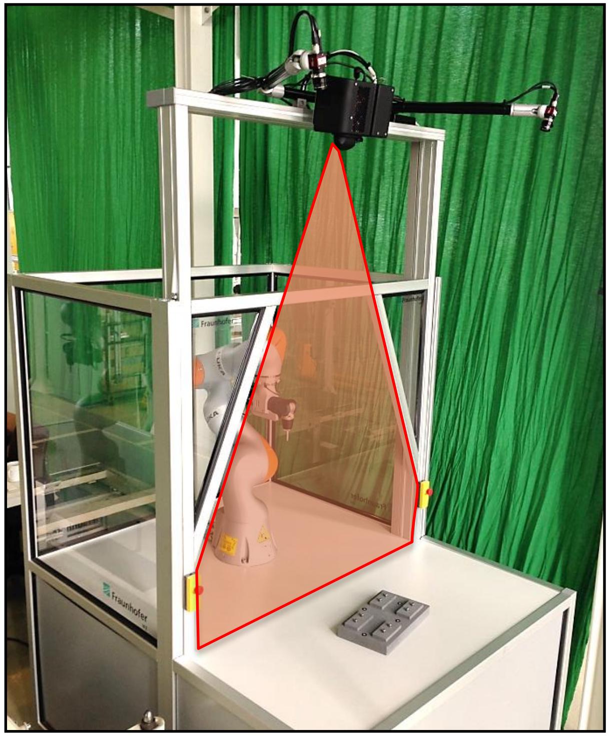
Example of current tools

- A projection based workspace monitoring system for speed and separation monitoring has been developed in H2020 Project 4x3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 637095.



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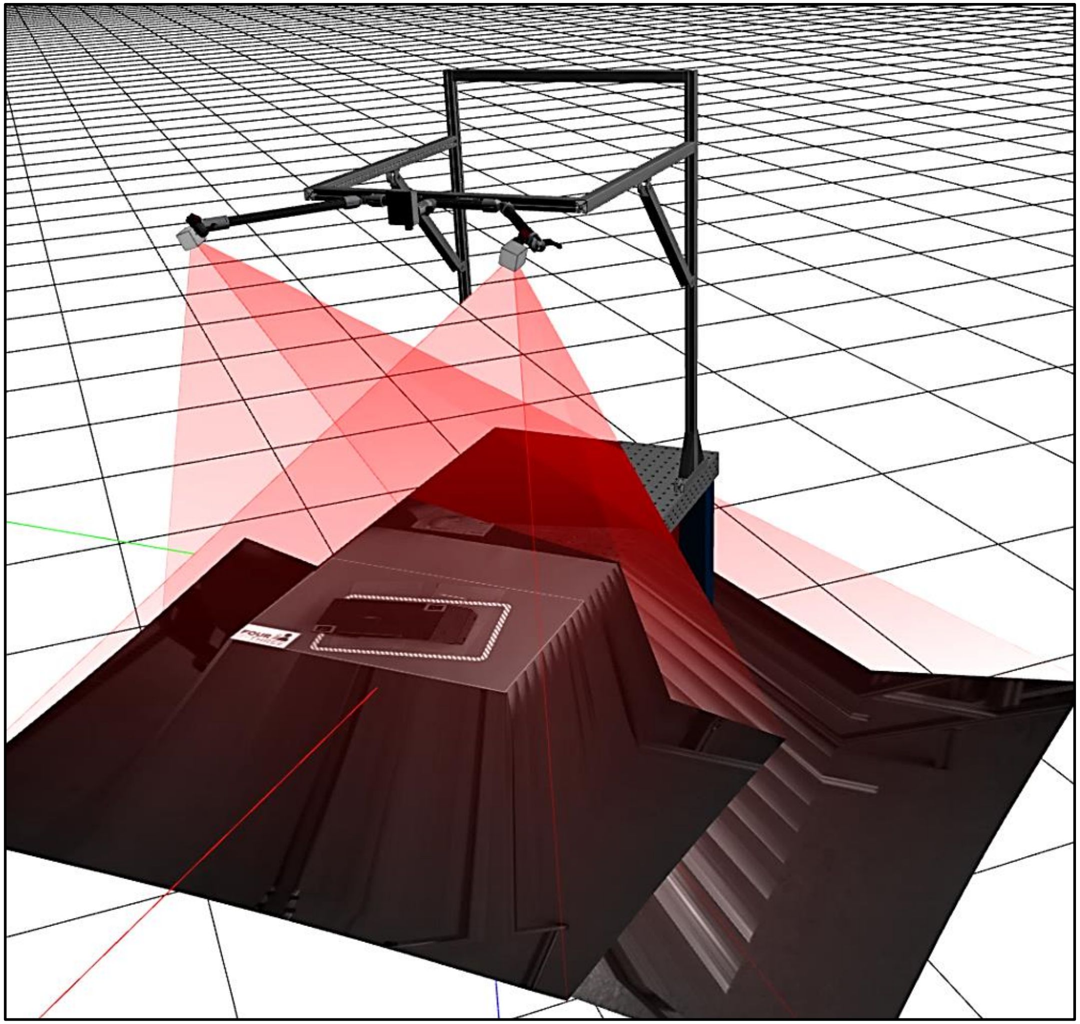
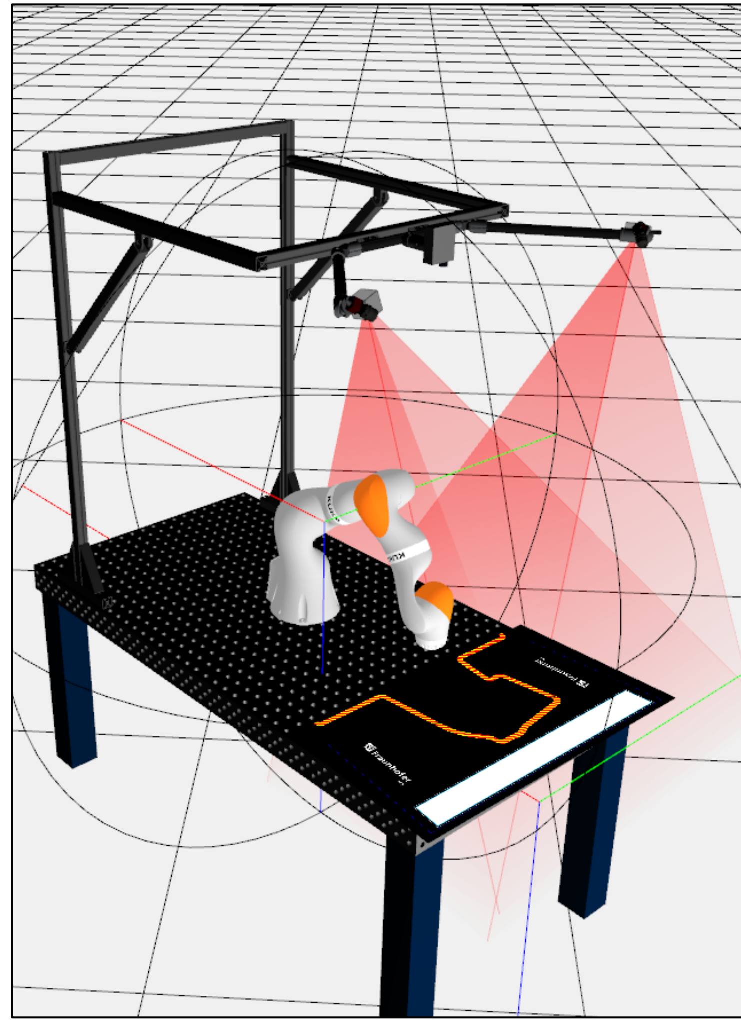
Example of current tools





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Study: Determination of biomechanical stress limits

- Objective
  - Determination of verifiable stress limits / thresholds of pain onset and injury onset (criteria for stopping tests: swelling or bruise)
  - Development of an evaluated and statistically significant table on pain and injury onset thresholds (ISO/TS 15066)
- Further objectives:
  - Correlation between load und strain (loading variables include: geometry, area, velocity, mass)
  - Testing the dependence between pain and injury onset (minor injuries)
- Approach: Collision experiments with volunteers

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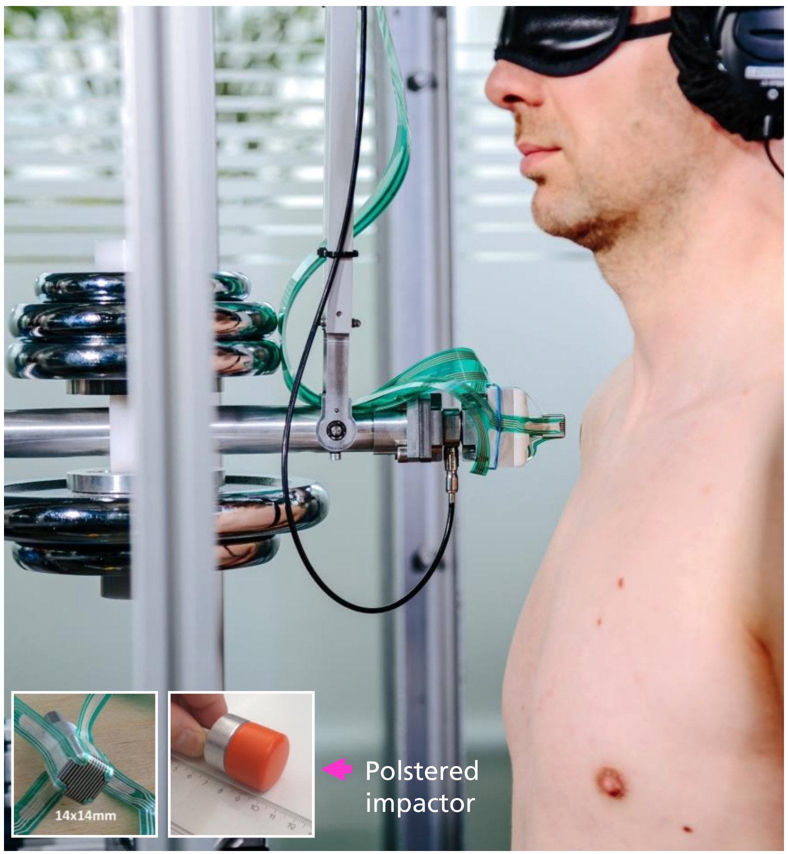
Study: Determination of biomechanical stress limits

Dynamic pain and injury onset
(Studies 1 and 2)



Quasi-static pain onset
(Study 2)

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Studies on Human-Robot Collisions
Experiment: injury onset

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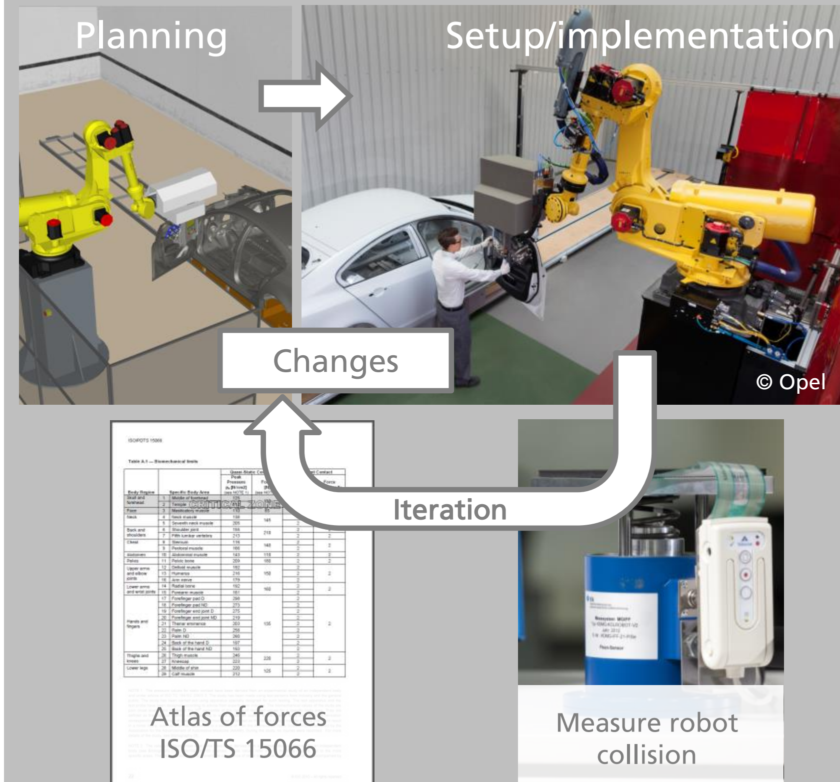
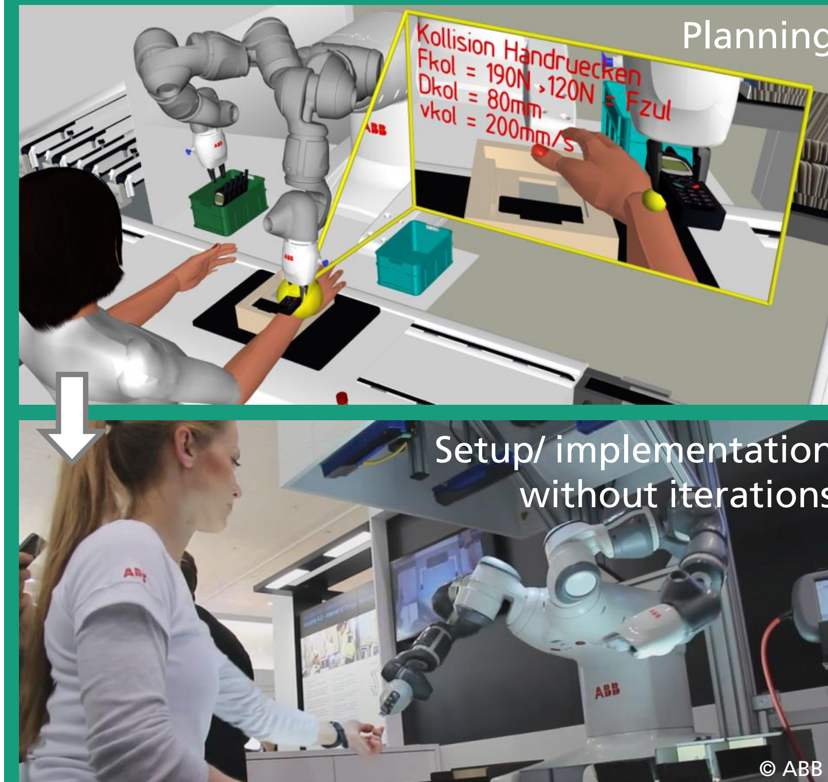
Our vision for CAS

Approach today



Safety verification can first be done on real set-up, long process with high integration efforts

Future planning/simulation tools



Safety verification possible during planning for early information about economic viability

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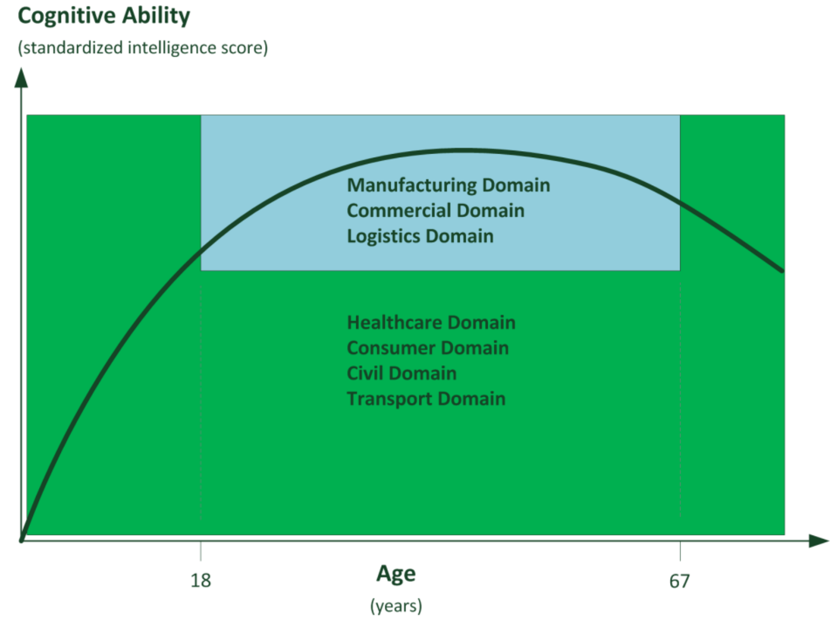
Implications

- Simplify robot programming
  - Expert knowledge no longer necessary
  - Organizational aspects
  - Human factors
- AI and safety
  - AI Sequencer
  - Reactive motions based on sensor input not previously validated
  - Transparency and acceptance



Lower economic cost of robotic systems

Open up new domains

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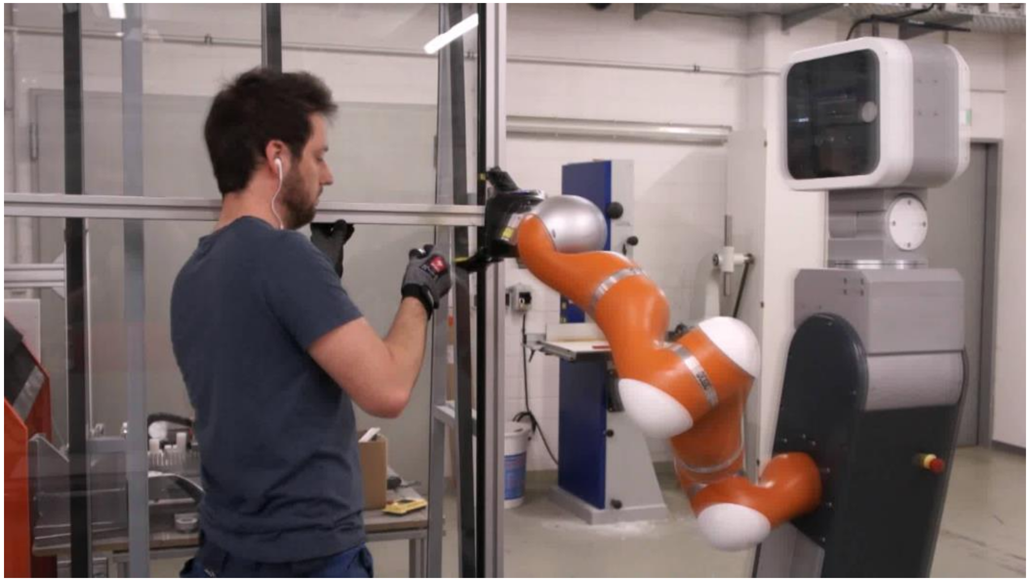
Implications

- Move verification from design-time to run-time

Where are limits of digital risk analysis?



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