SICHERE MENSCH-ROBOTER-KOLLABORATION
SAFE HUMAN-ROBOT COLLABORATION

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Fachtagung
„Assistenzrobotik und Mensch-Roboter-Kollaboration”
Fraunhofer IFF, Magdeburg
Human-Robot Collaboration
Challenges and Motivation...

Challenges
- Demographic change
- Shortage of skilled labor
- High-wage manufacturing
- Higher efficiency
- Better quality
- Novel product concepts

Motivation
- Relieving humans from exhausting activities
- Flexible automation
- Combination of robot and human capabilities
- Increased efficiency and quality
- New workcell concepts without fences

Research foci of the Fraunhofer IFF Robotic Systems Business Unit
- Mobile and stationary assistive robots
- New safeguarding technologies for human-robot collaboration
- Determination of biomechanical limit values for human-robot contacts
- Intuitive human-robot collaboration
Please note that…

- Collaborative robots cannot be provided with a CE mark, but with a declaration of conformity, since they are considered as partly completed machinery.
- Safety-rated robot control with essential safety functions (position and speed monitoring) and sensors (both in safety category PL d) are mandatory.
- The entire collaborative application must be subjected to a risk assessment.

Conclusion

- A comprehensive risk assessment is mandatory.
- The complete workcell must be considered (incl. scenario, fixtures, grippers, workpiece, robot, sensors, layout, etc.).
- There is no safe robot or safe sensor.
Human-Robot Collaboration
Research Foci of the Fraunhofer IFF

Technologies for all safety concepts
- Speed and separation monitoring
  - Projection-based workspace monitoring
  - Capacitive proximity detection
  - Tactile flooring
- Hand-guiding
  - Tactile dead-man switch
- Power and Force Limiting
  - Inherently safe robots
  - Tactile sensors on robots

Complementary work
- Investigation of human-robot contacts
  - Determination of verified limit values
  - Examination of injury influencing factors and quantities
- Collision tests with robot
  - Mechanical risk assessment
  - IFA measurement instrument
Speed and Separation Monitoring
Projection-based Sensor System

- Consists of
  - At least one projector
  - At least one camera
  - Structured light

- Projects a light curtain around the robot that marks the restricted space

- Any violation of the light curtain results in a shadow

- Shadows can be detected easily in the camera images

- Any detected violation leads to a protective stop
Speed and Separation Monitoring

Tactile Flooring

- Monitoring the restricted space around a robot
- Restricted space is adapted to the robot motion
- Consists of pressure sensitive floor mats with high resolution
- Detects any violation of the restricted space
Speed and Separation Monitoring
Capacitive Sensors for Proximity Detection

- Electrical fields for detecting violations of minimum distances
- Approaching objects change the capacity between field electrode and ground
- Can be combined with tactile sensors
Hand-g Guiding

Safe Hand-guiding Device for Large Industrial Robots

- Force control for hand-guiding
- Gravity-free guidance of heavy parts
- Dead-man switch integrated into the hand device for guiding the robot
- Dead-man switch is realized with tactile sensors
- Applicable for all kinds of industrial robots (incl. robots for large payloads!)
Power and Force Limiting
Tactile Sensors for Collision Detection and Interaction

- Sensitive material changes its electrical resistance under mechanical pressure
- Allows for collision detection and tactile interaction
- Spatial resolution (wide range) and pressure sensitivity
- Can be combined with shock-absorbing layers for reducing contact forces
Power and Force Limiting
Inherently Safe Robots

- Ultra-light robot manipulator
- Made of aluminum (links) and reinforced plastics (joints, gripper)
- Cable-driven (heavy actuators are located in an external motor unit)
- Collision forces are below any threshold
- Joints are mechanically compliant
Power and Force Limiting
Verification of Collaborative Workcells

- Instrument of the German Institute for Occupational Safety (IFA)
- Examination of robots regarding their dynamic collision characteristics
  - Contact force
  - Contact pressure
- Instrument allows for simulating human body parts (combination of a damping material and a spring)
- Determination of appropriateness for HRC and maximal allowable robot velocities – in compliance with thresholds of ISO TS 15066

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Power and Force Limiting

IFF Studies on Biomechanical Limit Values

- Examination of the onset of pain and injury due to dynamic human-robot collisions
- Determination of limit values and pain / injury relevant quantities
- Analysis of correlation between pain and injury
- Stop criteria:
  - Injury onset: swelling, bruise, moderate pain
  - Pain onset: occurrence of slight pain
- Development of verified and statistically meaningful thresholds for pain and injury onset
- Ethical approval by the University of Magdeburg
- Experimental setting: Mechanical pendulum

Diagram:

1. Stiff Frame
2. Stiff Rack
3. Fixing Devices
4. Vacuum mat
5. Ram
6. Impactor incl. Pressure Sensor
7. Additional Masses
8. Locking Mechanism
9. Load Cell
10. Precise Potentiometer
Power and Force Limiting
IFF Studies on Biomechanical Limit Values

Study 1 – Injury Onset
- Since 2013
- Financial support by KUKA and Daimler

Study 2 – Pain Onset
- Pain onset for dynamic edged and plane contacts
- Since 2015
- Initiated and funded by BGHM

Consortium

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- Experimental design
- Execution of the experiment
- Result analysis
Power and Force Limiting
IFF Studies on Biomechanical Limit Values

Study 1 – Injury Onset
- 15 test subjects
- 4 localizations (primarily)
- Three different masses (5kg, 10kg and 15kg)
- Three different impact contours

Study 2 – Pain Onset
- 20 test subjects
- 21 localizations
- Two different masses (5kg and 15kg)
- Two different impact contours

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Any questions? Don’t hesitate to contact us…

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