

Safe Human-Robot Co-Existence

Aaron Pereira

TU München

February 3, 2016

Course Aim (Learning Outcomes)

- You understand the **challenges** behind safe HRC in today's society
- You can **critique and appraise** approaches to HRC
- You gain **practical experience** of experiments on a real robot

Course Structure

Individual project (main focus)

- Topic assignment: now until start of SS 2017 (mid April)
- Presentation: middle-end of August
- Report: due August 31st

Series of lectures and discussions

- understand and critique state of the art
- understand the setup (robot, motion capture system, simulation)

Experience with user study

- Some of the projects are not practical but simulations: this allows you to get some user experience on a real system.

Available projects

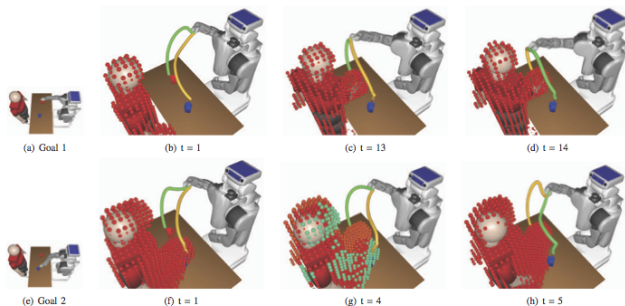
- 1 Online replanning based on human intention recognition
- 2 User study of different human-aware robot behaviours
- 3 Comparison of online verification with static safety zones
- 4 On the fly adaptation of robot safety algorithm to different kinematics on a modular robot
- 5 Human robot cooperation in car manufacturing: acquisition and replication of a demonstrated path
- 6 Scaling trajectories to avoid actuator saturation given uncertain dynamics
- 7 Implementation and Comparison of the State of the Art Path Planning Algorithms
- 8 Implementation of online trajectory planning methods.

This is the largest part of your work. For projects 1-4, the supervisor is Aaron Pereira, for 5 and 6 the supervisor is Andrea Giusti and for 7 and 8 the supervisor is Esra Icer.

1. Online replanning based on human intention recognition

- research and implement probabilistic approaches to recognise human intention and predict future movement,
- implement replanning of the robot trajectory to avoid an expected collision with the predicted human movement.

Working in simulation; if time allows, possibly testing on robot.



source: Mainprice and Berenson [3]

2. User study of different human-aware robot behaviours

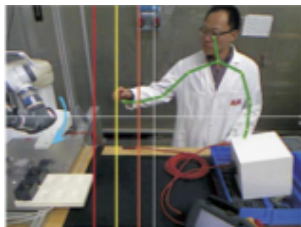
- Design and organise long-term user study to compare human acceptance of two approaches to human-aware control
- Collaborate with colleagues from Lehrstuhl für Ergonomie



Freeze-frame from user study

3. Comparison of online verification with static safety zones

- In HRC in industry, the usual way of implementing safety is static safety zones.
- We have a method to construct safety zones online and “dynamically” .
- Compare both methods to test the advantages of both.



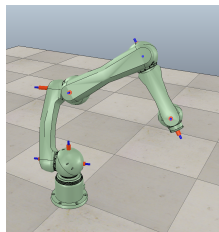
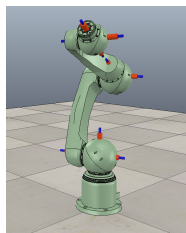
Source: Zanchettin et Al. [2]

4. On the fly adaptation of robot safety algorithm to different kinematics on a modular robot

We have an algorithm to control a robot safely around humans. But what if that robot can be reconfigured into different forms? Challenges include:

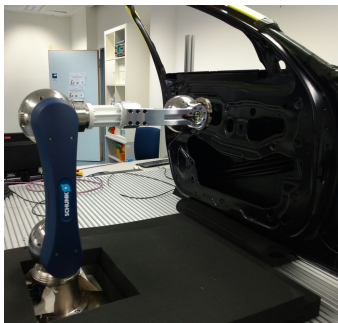
- automatic generation of the robot's spatial occupancy,
- checking for self-collision and
- identifying possible clamping hazards.

You would work mostly in simulation.



5. Human robot cooperation in car manufacturing: acquisition and replication of a demonstrated path

An application in car manufacturing is the gluing of insulation onto a car door, in which a robot must trace a path on the inside surface of the car door while applying a force.



Schunk Robot with extra module, car door

5. Human robot cooperation in car manufacturing: acquisition and replication of a demonstrated path

For this application we will use different assemblies of a modular robot considering that:

- the kinematic and dynamic model will be generated on the fly;
- the robot will be set in zero-G mode for each new configuration and a human worker demonstrates the path that robot must take.

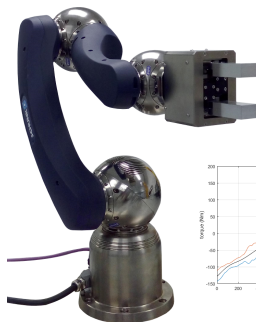
The robot should then duplicate this path while applying the correct amount of force for each meaningful configuration.

6. Scaling trajectories to avoid actuator saturation given uncertain dynamics

After a path is acquired (e.g. in the previous application), a corresponding trajectory is required for which it is important to consider that:

- joint positions, speed and torque limits must be respected;
- the dynamics of the robot might be uncertain e.g. the case where the dynamics and the parameters of the robot are unknown or vary for different payloads.

Set-based approaches can be employed such as interval-arithmetic-based algorithms for robot dynamics.



7. Implementation and Comparison of the State of the Art Path Planning Algorithms

Several approaches exist to plan a path for a robot in the environment with obstacles. There are two parts in this project:

- ① research on path planning approaches,
- ② implementation of them using OMPL (Open Motion Planning Library).

You would be working in simulation but if there is time you would test the algorithms on Schunk LWA 4P robot.

8. Implementation of online trajectory planning methods

We have an algorithm to generate a collision-free trajectory in the environment consisting of dynamic obstacles. The task is to:

- take data from sensors and use them to localise the obstacles,
- plan the collision-free trajectory.

The task mainly consists of implementing the algorithm on MATLAB and testing it on the Schunk LWA 4P robot.

Lectures and Discussions

Planned lectures/discussions are:

- ① Introduction to safe, human aware robot control
- ② Introduction to hardware and software in the lab
- ③ Discussion: themes within safe human-robot co-existence I
- ④ Discussion: themes within safe human-robot co-existence II
- ⑤ Introduction to user study
- ⑥ Guest Lecture (from another chair or university, t.b.c.)

Lectures

Duration 1 hour. Dates to be set on agreement with all course members.

Discussion

Each student chooses a current (< 2 years old) paper to read, which they present in 5-10 minutes during the session. After all presentations, there is a 30 minutes round-table discussion. This is not graded.

Interested?

...or have any questions? Please get in touch!

- Organise a meeting with the supervisor (Aaron/Andrea) with the topic you are interested in, or suggest a new topic.
- places will be allocated via the matching system

Contact: aaron.pereira@tum.de, giusti@in.tum.de

Literature

For projects 1-4:

- Hadaddin et al.: Collision Detection and Reaction: A Contribution to Safe Physical Human-Robot Interaction (IROS, 2008)
- Zanchettin et al.: Safety in Human-Robot Collaborative Manufacturing Environments: Metrics and Control (T-ASE, 2016)
- Mainprice & Berenson: Motion planning for human-robot collaborative manipulation tasks using prediction of human motion (RSS, 2014)
- Pereira & Althoff: Overapproximative arm occupancy prediction for human-robot co-existence built from archetypal movements (IROS, 2016)

Literature

For project 5:

- Giusti and Althoff: Automatic centralized controller design for modular and reconfigurable robot manipulators. (IROS, 2015)

For project 6:

- Siciliano et. al. Robotics: Modelling, Planning and Control. Springer, 2009. Section 7.7
- Hollerbach: Dynamic Scaling of Manipulator Trajectories (J. Dyn. Sys. Meas. 1984)