Towards Intuitive Industrial Human-Robot Collaboration

System Design and Future Directions

Ferdinand Fuhrmann, Wolfgang Weiß, Lucas Paletta, Bernhard Reiterer, Andreas Schlotzhauer, Mathias Brandstötter
Outline

- Introduction
- State-of-the-art
- Background
- The CollRob Project
  - Models, Functionalities and Use Cases
- Outlook
Introduction

General

- Human-Robot-Collaboration buzz-word in I4.0
  - Industry prepares first use cases – with certain limitation

- What is Collaboration?
  - Combining skills and expertise to jointly achieve a goal
  - Collaboration very high-level process involving causal and non-causal cognitive activities
Introduction

Project **CollRob**

- 4-year funded research project
- 8 research groups involved
- **Aim 1:** Enable H-R Collaboration
  - Planning
  - Interaction
  - Safety
- **Aim 2:** design application scenarios
State-of-the-art (1)

Industrial point-of-view

- Availability of sensitive and lightweight robot arms which are safe enough to team with people
- Simple interactions between humans and robots
- Slow and therefore safe
- Little integration of the human aspects
- Implemented use cases
  - Collaborative assembly
  - Service robots
Recent advances in artificial intelligence topics
- Natural language understanding, machine vision
- Collecting, merging and analyzing vast amount of data
- Machine learning and deep learning
- Autonomous systems
- …

Progress in research on
- Social robots, assistant robots
- Intelligent personal assistant, virtual assistants
- Chatbots, Spoken dialog systems

Availability of autonomous and intelligent consumer products
- Amazon Alexa, Siri, Cortana, …
- Pepper (SoftBank), Sony AIBO, …
- … and many more
Collaboration

- Concepts and models for H-H collaboration extensively researched by psychology
- Basic characteristics of collaboration [1]
  - Shared activity
  - Joint intention
  - Common ground
- Shared cooperative activity features:
  - Mutual responsiveness
  - Commitment to the joint activity
  - Commitment to mutual support

A New Framework for Human-Robot-Collaboration

High-level CollRob Model

- Interaction
- Negotiation
- Communication
- Trusworthiness
- Persuasion
- Coordination
- Perceptiveness

HRC
Human-Robot-Interaction

- Intuitive Interaction
  - Natural Interaction is multimodal: Speech, Gaze, Gesture, ...
  - Coupled Modalities: More natural, More robust!
  - Context-sensitive feedback: relevant information!

- Human-Factors
  - Situation Awareness
  - Stress
Modelling HRI

- Enabling intuitive Interaction and Communication
- Plan and decide what to communicate through which channel

- Theory-of-mind models
  - Is the human relaxed or stressed?
  - Is she focused on her task?
  - Does she know if I finished my task?
  - Is the human aware of the goal and the steps how to reach the goal?
Planning for Collaborative Agents

- Domain-independent planning towards collaborative autonomy
  - Knowledge is updated by sensor data
  - Find actions for human-robot team to solve current problem

- Specific challenges in collaborative systems
  - Dynamic environment
  - Safety
  - Interaction
Safety Aspects in Human Robot Collaboration

- Integrity of human health
- Safety in mobile manipulation and dynamic environments
- Ergonomics of work places
- No safety without security

Safety verification by measuring the biomechanical load regarding ISO/TS15066
Targeted Use Cases

- Building collaboratively tangram figures as a representative for an assembly task in the industry
  - One Person and one serial manipulator
  - Sharing a common workspace
  - Working at the same time

- A sensitive mobile manipulator
  - Delivering parts to workplaces
  - Moving area is shared with other humans
Evaluation of HRI:
Human factors study on situation awareness

- 12 participants, moderated, dual task:
  - **Primary task**: Read aloud (up to 6 pages at laptop),
  - **Secondary task**: timed hand-over (domino brick)
  - **Robot cycle** until hand-over event (cycle duration 18-26 sec.)
  - OptiTrack mocap, eye tracking glasses 30 Hz, ABB Yumi robot, gripper, ROS synchronisation

- **Results**:
  - Real-time eye movement analysis
  - Attention features correlate with SAL
  - Classification of SAL with \(\approx 92\%\) accuracy
  - Prediction of HRI performance \(\approx 80\%\)
Next Research Questions

- Which granularity of communication between the human and the robot is needed to keep the human informed but not distracted from his work?
- How can the intention of the robot to the human be communicated to reduce (nearly) collisions between the agents and improve the performance of assembling parts?
- Which factors influence stress and perceived trustworthiness?
- How can the risk (of a collision) between the agents be described and predicted?
- Optimizing task planning for human robot teams when interaction results interfere the current plan
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