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MIN Faculty
Department of Informatics



Physical Human Robot Interaction

Intelligent Robotics Seminar

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Supportive

Collaborative

Cooperative

4. Control for Physical Interaction

Interaction Control

Learning and Adaptation

Collision Handling

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- ▶ Last decades: Possibly dangerous position-controlled rigid robots
- ▶ Goal: Safe, seamless, dependable physical human–robot interaction (pHRI) in the real domestic and professional world
- ▶ How?: Human centered design of robot mechanics



<http://www.patheos.com/blogs/azizpoonawalla/2016/06/brexit-dont-panic/>

- ▶ Industrial coworkers
- ▶ Mobile servants in the professional service sector
- ▶ Assistive devices for physically challenged individuals
- ▶ Service robots for the support of general household activities



<https://www.youtube.com/watch?v=Lh2-iJj3dI0>



Introduction

Motivation

Introduction

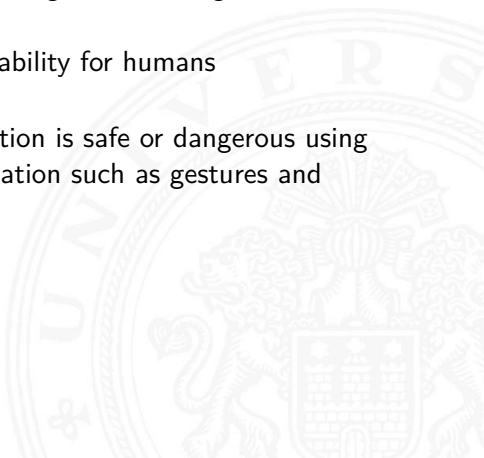
Classification

Control for Physical Interaction

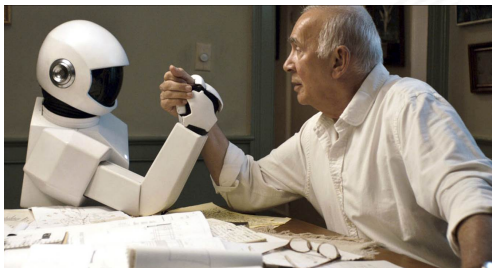
Conclusion

References

- ▶ Close, safe, and dependable physical interaction between human and robot in a shared workspace.
- ▶ Tight coupling of control, planning, and learning
- ▶ System usability and interpretability for humans
- ▶ Communicate whether a situation is safe or dangerous using verbal or nonverbal communication such as gestures and emotional feedback



- ▶ pHRI can be generally classified across three categories of interaction: **supportive**, **collaborative**, and **cooperative**
- ▶ Ordered by increasing frequency and necessity of physical contact with the robot and level of proximity to the user



www.interaction-design.org/literature/article/human-robot-interaction-stop-getting-romantic-with-your-robots



Classification

Supportive

Motivation

Introduction

Classification

Control for Physical Interaction

Conclusion

References

- ▶ Robot is not integral to the central performance of a task
- ▶ Instead provides the human with the tools, materials, and information to optimize the human's task performance
- ▶ pHRI aspect: Safety and well-structured human-robot communication
 - ▶ Museum tour guide robots
 - ▶ Shopping assistant robots for aiding seniors
 - ▶ Homecare robots



Classification

Collaborative

Motivation

Introduction

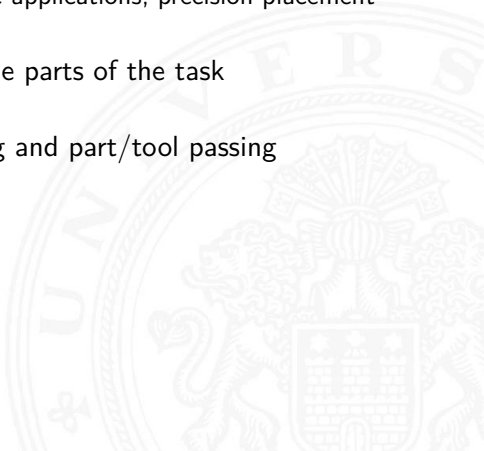
Classification

Control for Physical Interaction

Conclusion

References

- ▶ Labor divided between the robot and human
 - ▶ Human: Decision making
 - ▶ Robot: Repetitive, high-force applications, precision placement
- ▶ Each separately completing the parts of the task
- ▶ Interacting through turntaking and part/tool passing
- ▶ Physical space is often shared



Classification

Cooperative

Motivation

Introduction

Classification

Control for Physical Interaction

Conclusion

References

- ▶ Human and the robot work in direct physical contact
- ▶ Or indirect contact through a common object
- ▶ Continuous and cooperative shared control of the task.
 - ▶ Cooperative lifting and carrying
 - ▶ Coordinated material handling



<http://interactive-robotics.engineering.asu.edu/research/>



Control for Physical Interaction

Interaction Control

Motivation

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Classification

Control for Physical Interaction

Conclusion

References

- ▶ How to gently handle physical contact in robotics?
- ▶ Impedance control became the most popular interaction control paradigm in the pHRI

Instability on industrial robots with
interaction control in a fixed position
and variable environment impedance

<https://www.youtube.com/watch?v=bA4CtdYa36s>



Control for Physical Interaction

Interaction Control (cont.)

Motivation

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Control for Physical Interaction

Conclusion

References

Impedance Control

- ▶ The control of dynamic interaction between a manipulator and its environment
- ▶ This type of control is suitable for environment interaction and object manipulation in pHRI
- ▶ Control of position or force alone is inadequate; control of dynamic behavior is also required.



Control for Physical Interaction

Learning and Adaptation

Motivation

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Control for Physical Interaction

Conclusion

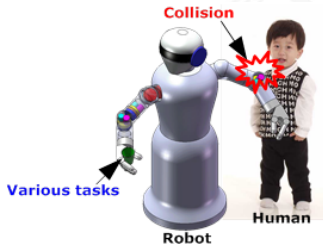
References

- ▶ pHRI – complex, evolving, high uncertainty, hard to be modeled explicitly
- ▶ Solution: learning and adaptation approaches
- ▶ Robot gains the ability to adapt its behavior
- ▶ Adapt force, trajectory, and impedance simultaneously
 - ▶ Biomimetic controller
 - ▶ Based on studies in neuroscience

Control for Physical Interaction

Collision Handling

- ▶ Handling of collisions between robots and humans
- ▶ Limiting possible human injury due to physical contacts
 - ▶ Collision detection phase
 - ▶ Collision isolation phase
 - ▶ Collision identification phase
 - ▶ Collision reaction phase





Control for Physical Interaction

Collision Handling (cont.)

Motivation

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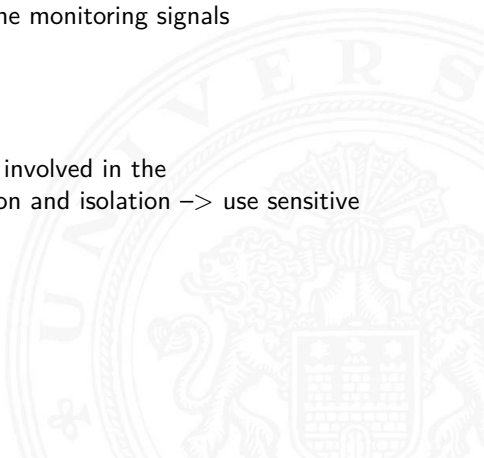
Classification

Control for Physical Interaction

Conclusion

References

- ▶ Collision detection phase
 - ▶ The occurrence of a collision
 - ▶ Selection of a threshold on the monitoring signals
- ▶ Collision isolation phase
 - ▶ Knowing which robot part is involved in the
 - ▶ Obtain both collision detection and isolation → use sensitive skins



Control for Physical Interaction

Collision Handling (cont.)

Motivation

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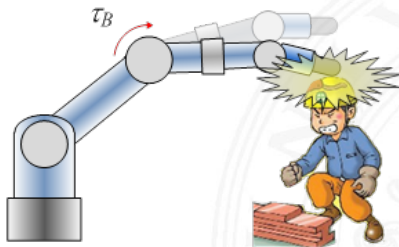
Classification

Control for Physical Interaction

Conclusion

References

- ▶ Collision identification phase
 - ▶ Directional information and the intensity of collision force
 - ▶ Cartesian wrench at the contact
 - ▶ Resulting joint torque during the entire physical interaction



<https://sites.google.com/a/korea.ac.kr/intelligent-robot-laboratory/manipulation/collision-safety>



Control for Physical Interaction

Collision Handling (cont.)

Motivation

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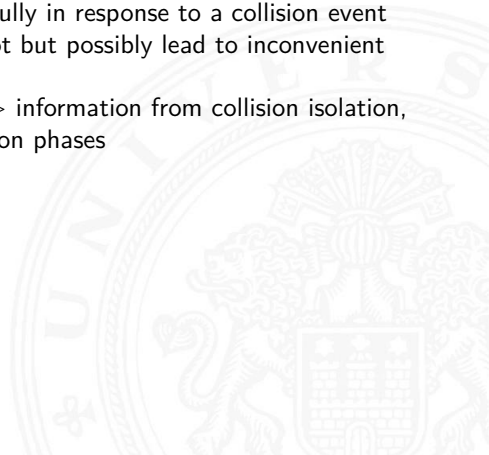
Classification

Control for Physical Interaction

Conclusion

References

- ▶ Collision reaction phase
 - ▶ Robot should react purposefully in response to a collision event
 - ▶ Simplest way: Stop the robot but possibly lead to inconvenient situations
 - ▶ Better reaction strategies → information from collision isolation, identification and classification phases





Control for Physical Interaction

Shared Manipulation Control

Motivation

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Control for Physical Interaction

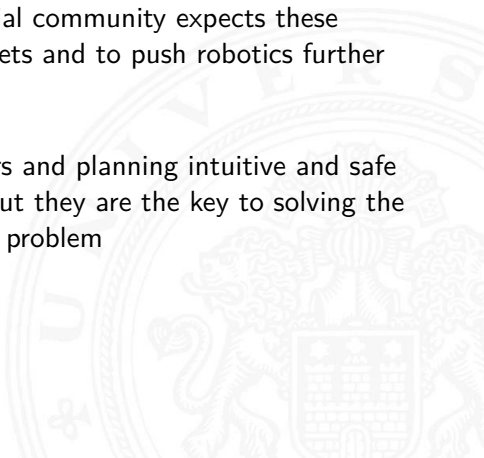
Conclusion

References

- ▶ Collaborative carrying, particularly of a long, large, heavy or flexible object
- ▶ Robotic and human partners will naturally take turns with leading and following roles depending on the state of a shared task.
 - ▶ Switching model
 - ▶ Robot changes its behavior from completely following to completely leading
 - ▶ Recently: Change behavior between leading and following based on its confidence in its predictions of the human user's intentions



- ▶ Rise of a new generation robots capable of physical interaction contributed to the large interest in pHRI.
- ▶ Robotics research and industrial community expects these systems to open up new markets and to push robotics further toward domestic applications
- ▶ Learning interaction controllers and planning intuitive and safe interactions are young fields but they are the key to solving the long-term physical interaction problem



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Thank You for Listening!