Towards Robot Whole-Body Collision Avoidance Using Distributed Sensing


Dominik Sieber
dominik.sieber@tum.de


Markus Wiedemann
m.wiedemann@tum.de


Sandra Hirche
hirche@tum.de

Motivation

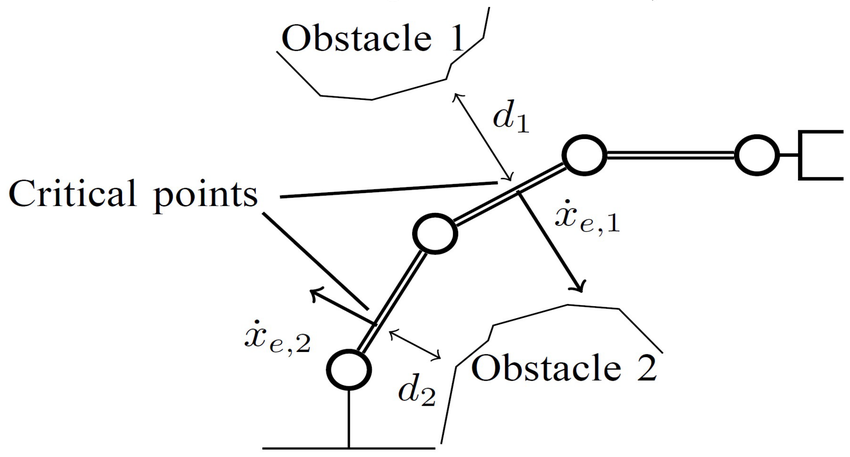
- Sensing of the complete environment is crucial in physical cooperative human robot interaction
- Comprehensive information of the environment by distributed whole-body sensing system

Challenges

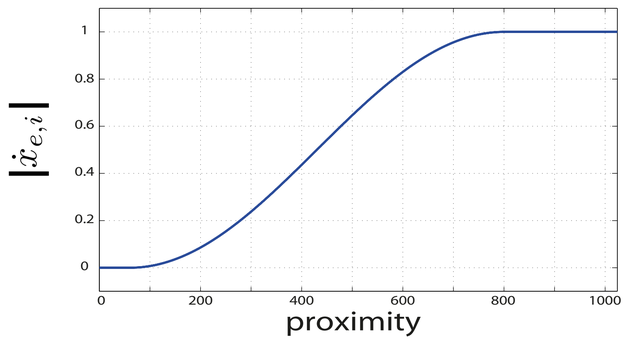
- State estimation and compliance control schemes
- Collision avoidance approach by exploiting the manipulator redundancy based on distributed proximity measurements
- Combination of real-time control architecture *ARCADE* and tactile sensors *HEX-O-SKIN*

Collision Avoidance Approach based on Jacobian Transpose Method

- Assumption: known sensor location on robotic manipulator
- Critical distances d_c measured by sensors



- Evaluation of escape velocities $\dot{x}_{e,i}$



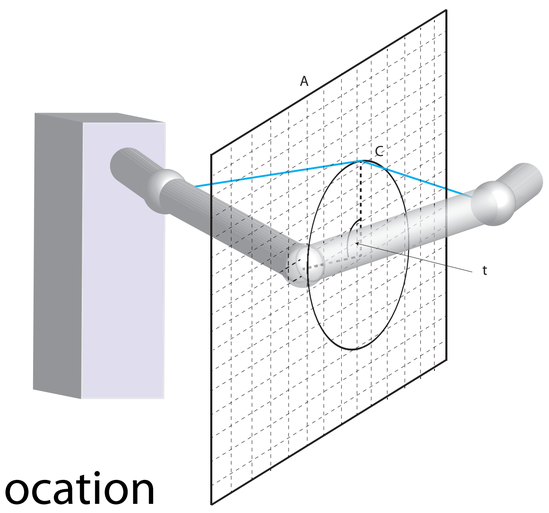
- Superpose $\dot{x}_{e,i}$ by Jacobian Transpose

$$\underline{\dot{q}}_0 = \sum_{i=0}^{N_{\text{obst}}} J_c^{\mathrm{T}} \underline{\dot{x}}_{e,i}$$

- Offline Calculation of $J_{c,i}(q)$ w.r.t. sensor location

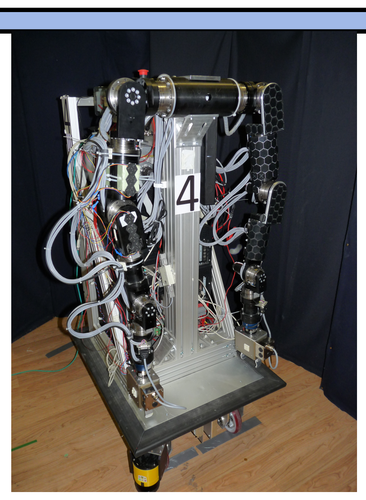
- Projection into null-space

$$\underline{\dot{q}} = J^{+}\underline{\dot{x}} + (I - J^{+}J)\underline{\dot{q}}_0$$



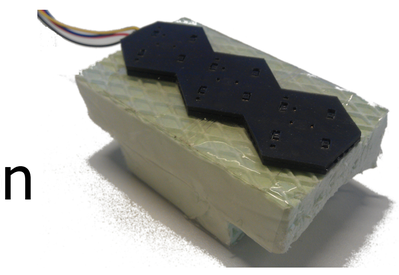
Mobile Manipulator

- Admittance-controlled 7 DoF robotic manipulators on mobile platform
- Force/torque sensor at wrist
- Data driven architecture ARCADE built on real time data base (RTDB)



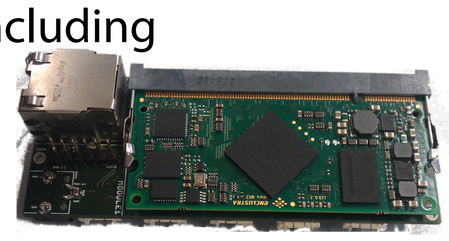
HEX-O-SKIN Sensors [Mittendorfer/Cheng 2011]

- Multi-modal sensor (proximity, acceleration, and temperature)
- Tactile Section Unit (TSU), a switch for sensor clusterings to robotic backbone



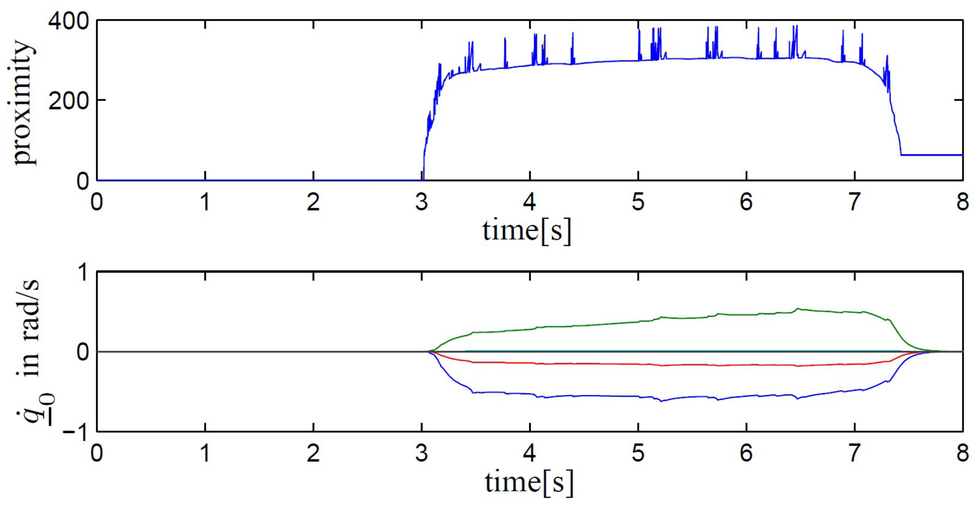
Physical and Software Integration

- Accurately fitting and removable covers
- Sensor data measurement in RTDB including unique sensor ID and positioning
- Easy extendability for higher sensor quantity by modular configuration



Experimental Results

- Avoiding collision with approaching human arm



- No deviation from main task by null space motion
- More detected obstacles or active sensors lead to higher null space velocity

Future Work

- Whole-body cover with HEX-O-SKIN sensors
- Automatic calibration of sensor location
- Situation-based collision avoidance prioritization

Selected publications:

- D. Althoff, O. Kourakos et al, "An architecture for real-time control in multi-robot systems", Human Centered Robot Systems, 2009
- B. Weber, T. Fritzsch, K. Kühnlenz, "Kollisionsvermeidung bei redundanten Manipulatoren mit Hilfe von Multi-Kamera Arrays", Forum Bildverarbeitung, 2010
- P. Mittendorfer and G. Cheng, "Humanoid multimodal tactile-sensing modules", IEEE Transactions on Robotics, 2011

TECHNISCHE UNIVERSITÄT MÜNCHEN

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ORDINARIUS: UNIV.-PROF. DR.-ING./UNIV. TOKIO MARTIN BUSS

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