Improving grasp and manipulation robustness through planning and compliant control

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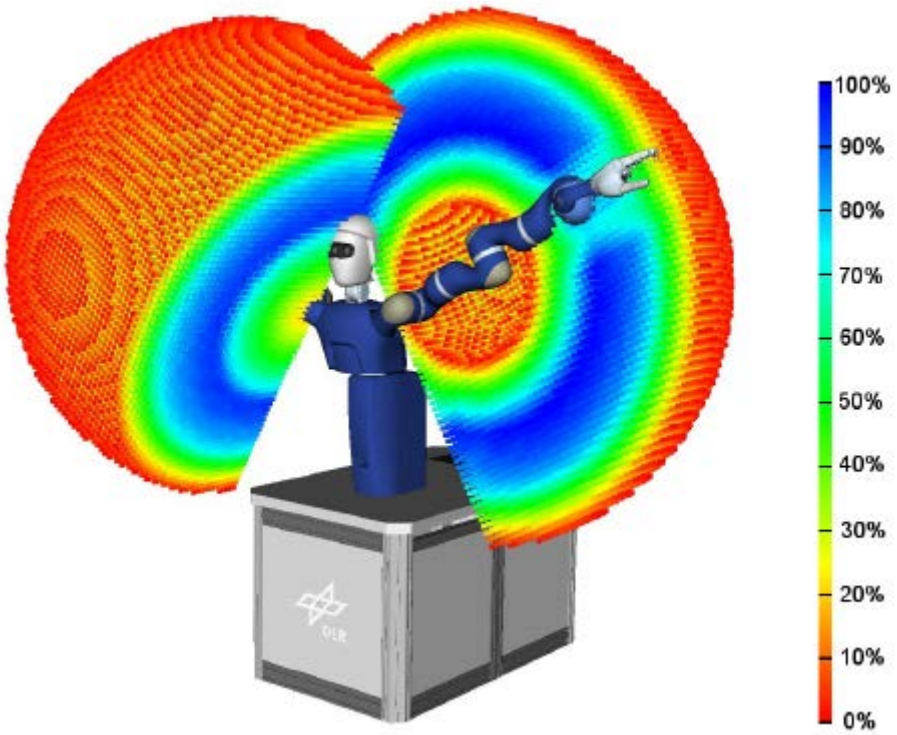
IROS 2016 Workshop: Closed-loop grasping and manipulation
Oct 14th, 2016

I. THE TOOLS

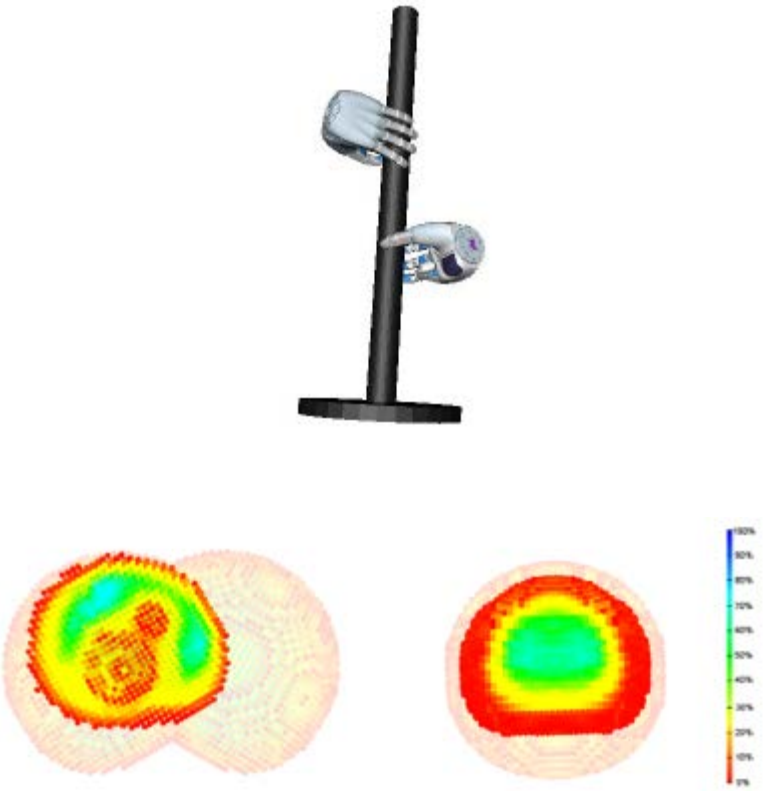
Encoding dexterity

Reachability + dexterity info = Capability map



[Zacharias, 2008-2012]

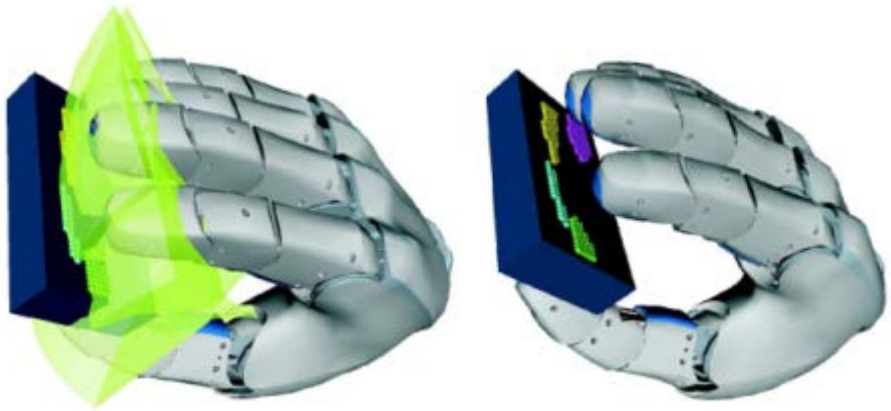
Application in dual-arm manipulation



[Sundaram, Porges, Roa, HUMANOIDS'16]

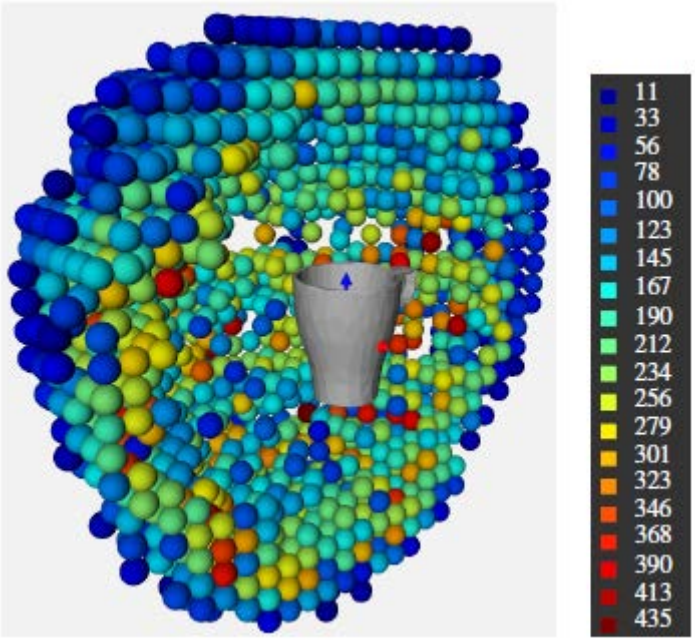
Encoding grasping ability

Independent contact regions



[Roa, Suarez, TRO 09]

Graspability map



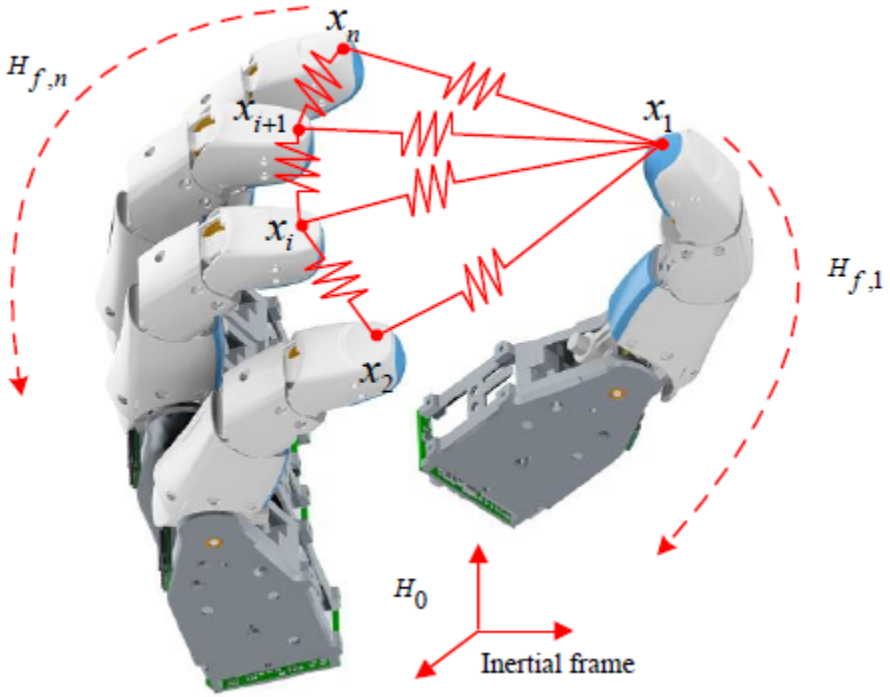
[Roa, Hertkorn et al., IROS'11]

Application in assistive robotics

Video attachment to

“ Flexible, Semi-Autonomous Grasping for Assistive Robotics.” J. Vogel, K. Hertkorn, R.U. Menon, M.A. Roa. IEEE Int. Conf. on Robotics and Automation – ICRA 2016.

Compliant control for grasping: multi-finger impedance



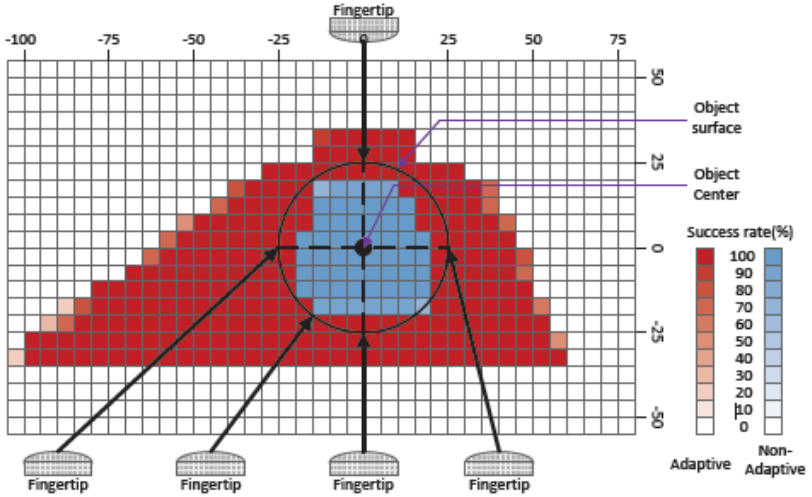
[Chen, Roa et al, ICRA15]

Functional evaluation: robustness against pose uncertainties

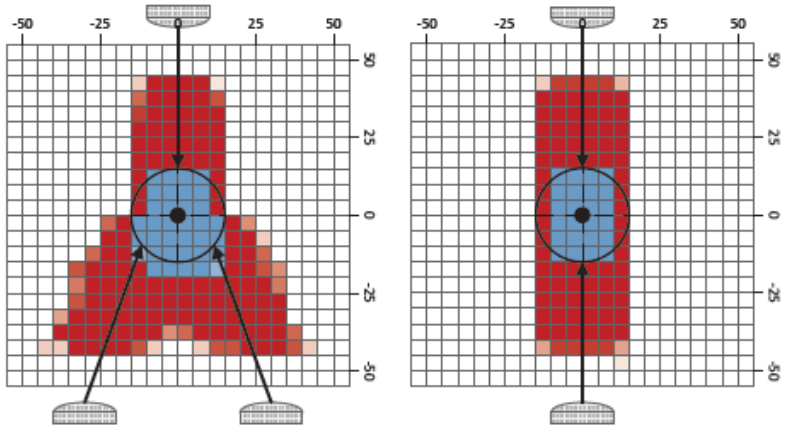
Video attachment to
“An adaptive compliant multi-finger approach-to-grasp strategy for objects with position uncertainties.” Z. Chen; T. Wimbock; M.A. Roa; B. Pleintinger; M. Neves; C. Ott; C. Borst; N. Lii. ICRA 2015.
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=7139881

[Chen, Roa et al, ICRA15]

Increase in robustness



(a) 5-finger grasp



(b) 3-finger grasp

(c) 2-finger grasp

[Chen, Roa et al, ICRA15]

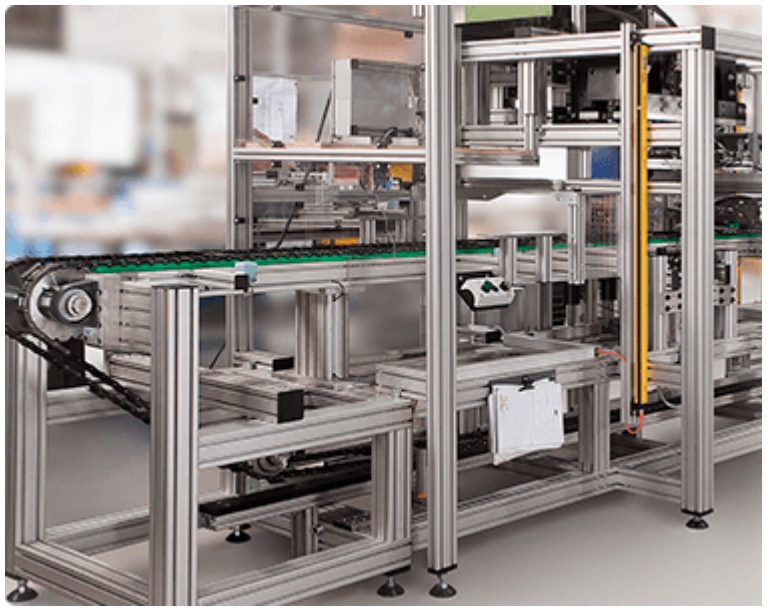
TOOLBOX

- Reachability/capability map: arm dexterity
- ICRs: grasp robustness in planning
- Graspability map: hand ability (for a given object)
- Finger-level impedance control: active compliance
- Variable stiffness hand design: passive/active compliance

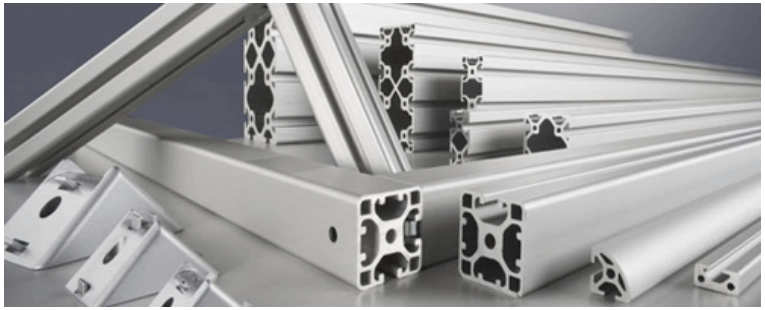
II. TOWARD INDUSTRY 4.0 APPLICATIONS

Case 1: Flexible assembly using a modular construction set

Maschinenbau Kitz GmbH

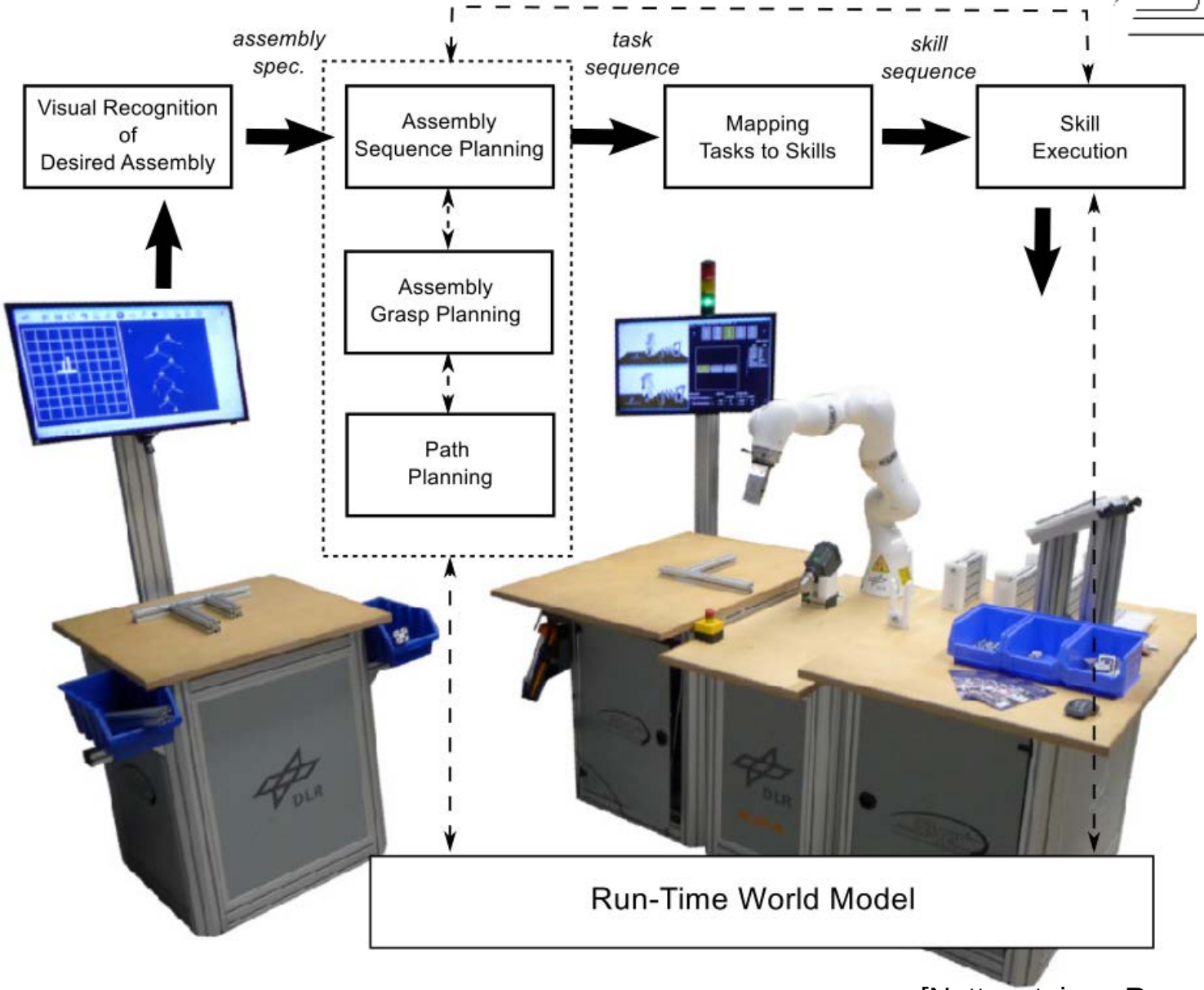


FMS Montagetechnik GmbH



Item Industrietechnik GmbH

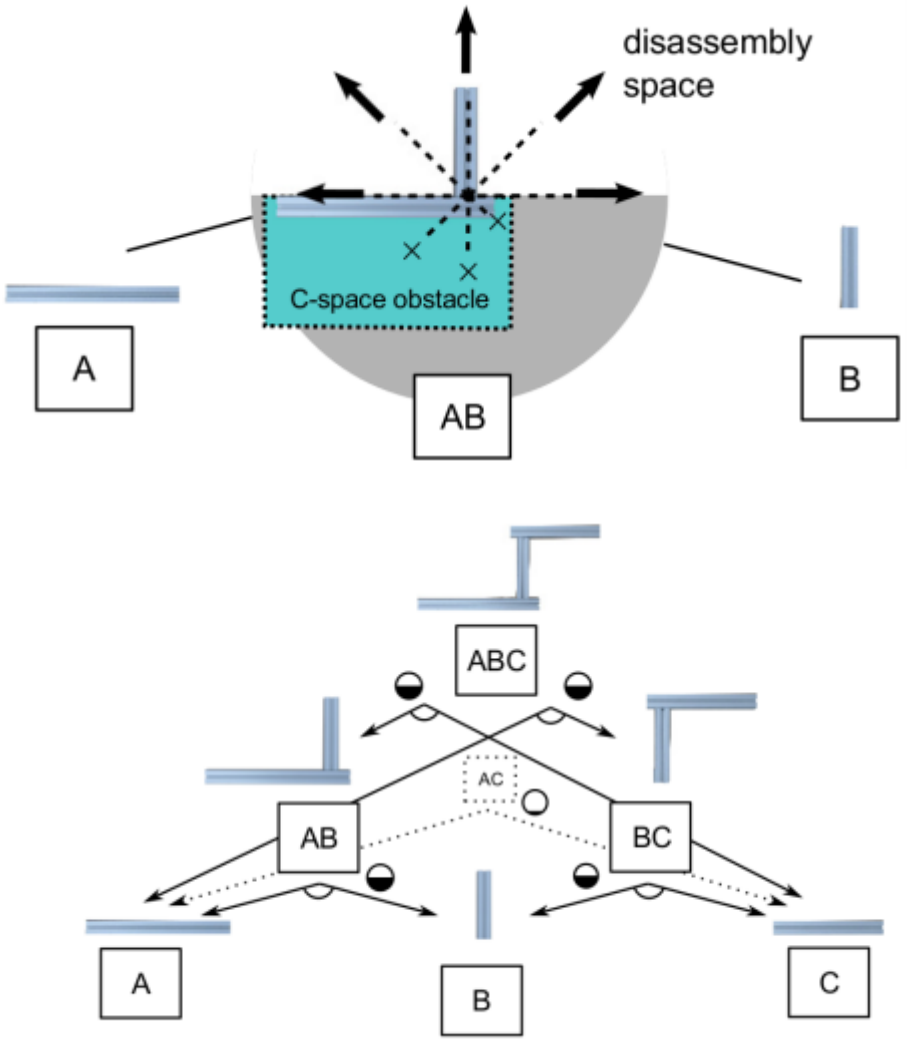
DLR



[Nottensteiner, Roa et al., ISR'16]

Assembly Sequence Planning

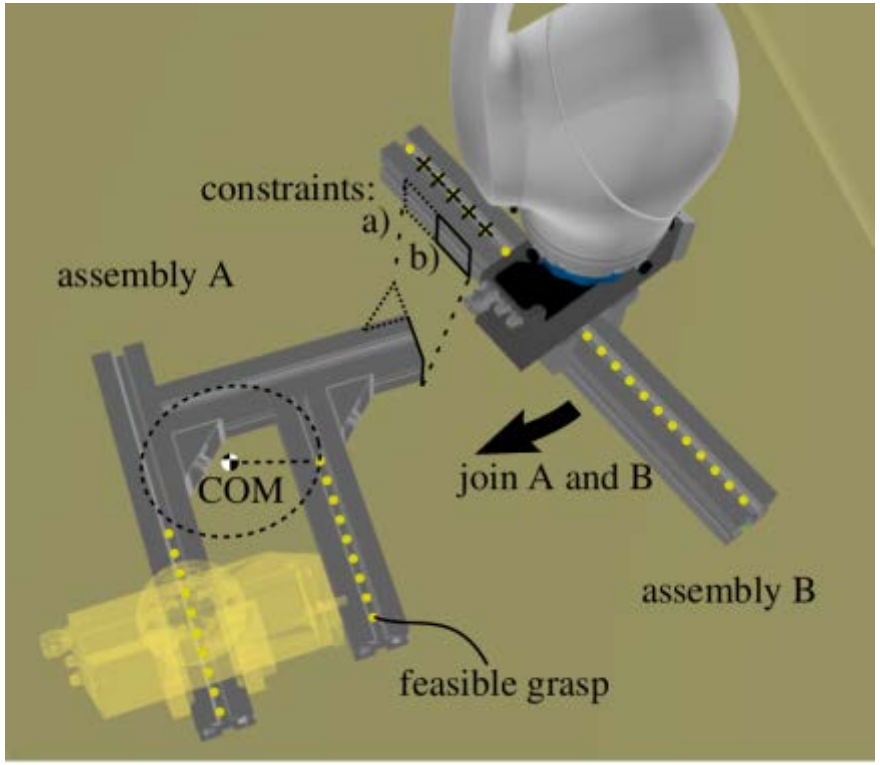
- Feasible sequences generated through analysis of dissassembly
- Generation of AND/OR graph to store variants of sequences
- Evaluation of graph considering feasibility, preferred mating actions,…



[Nottensteiner, Roa et al., ISR'16]

Assembly & Grasp Planning

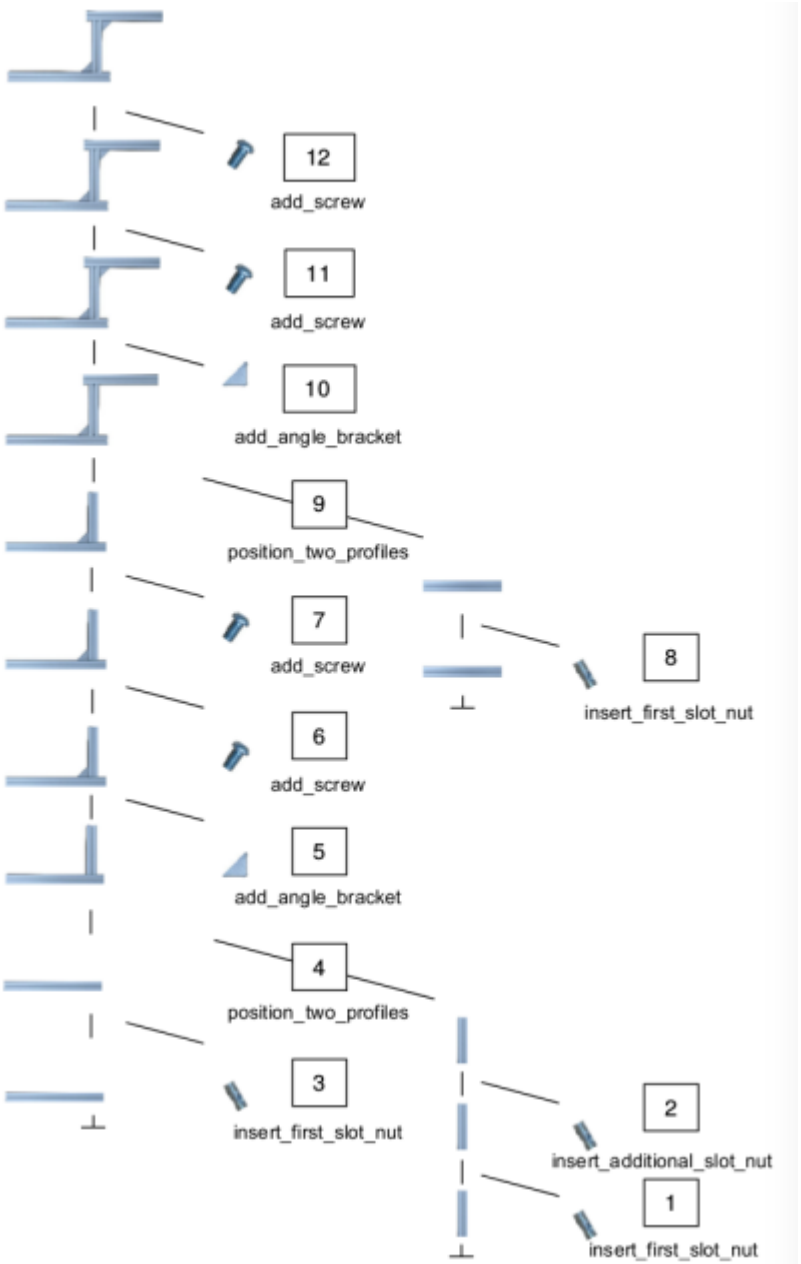
- Considered constraints:
  - Due to the subassembly
  - Due to the joining action
- Quality criterion:
  - distance to COM



[Thomas, Roa et al., CASE'15]
[Nottensteiner, Roa et al., ISR'16]

Task Pattern Classification

- Example of a generated sequence
- Classification of assembly tasks
- Four major task types:
  - *Insert_slot_nut*
  - *Add_angle_bracket*
  - *Add_screw*
  - *Position_profiles*



[Nottensteiner, Roa et al., ISR'16]

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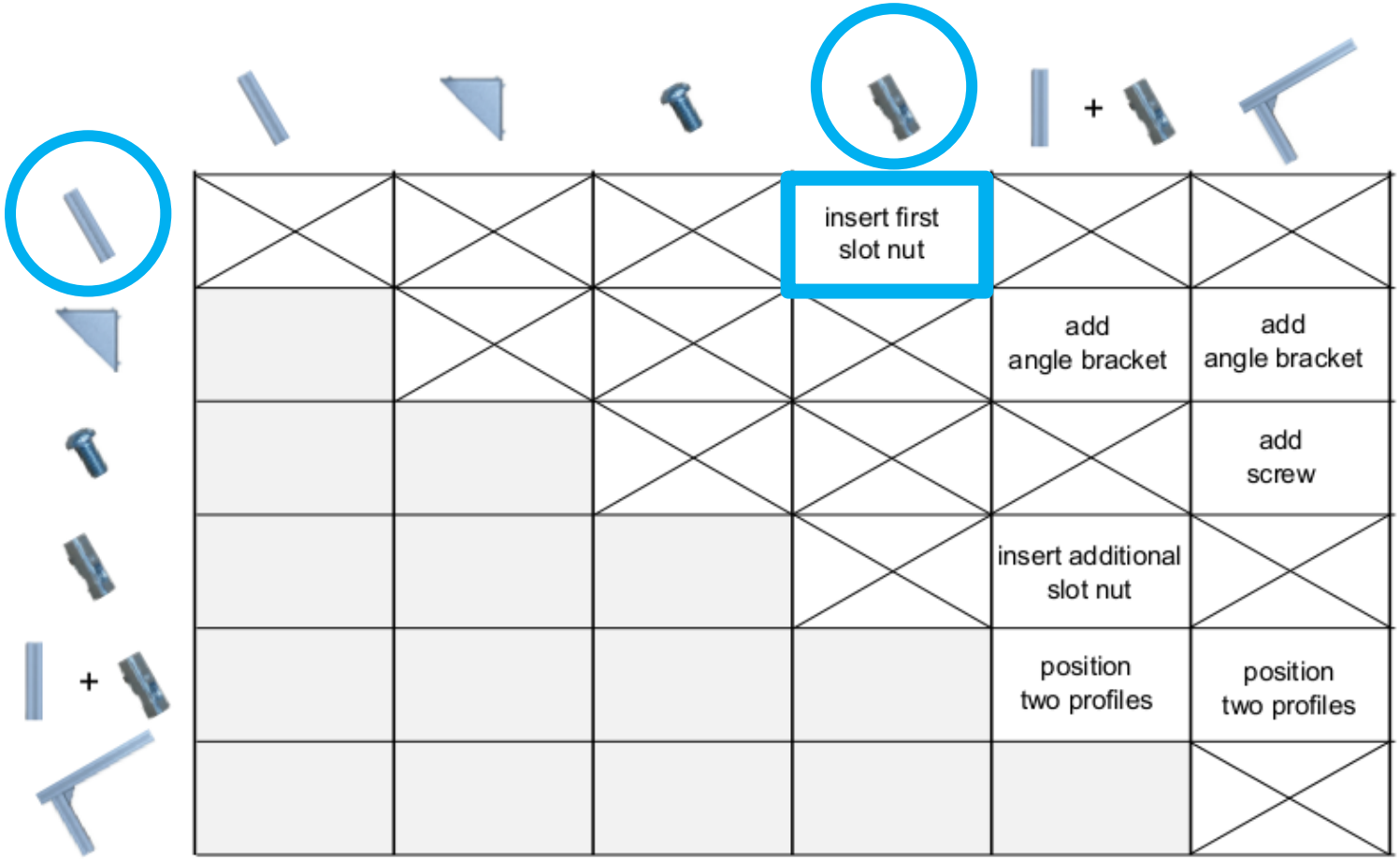
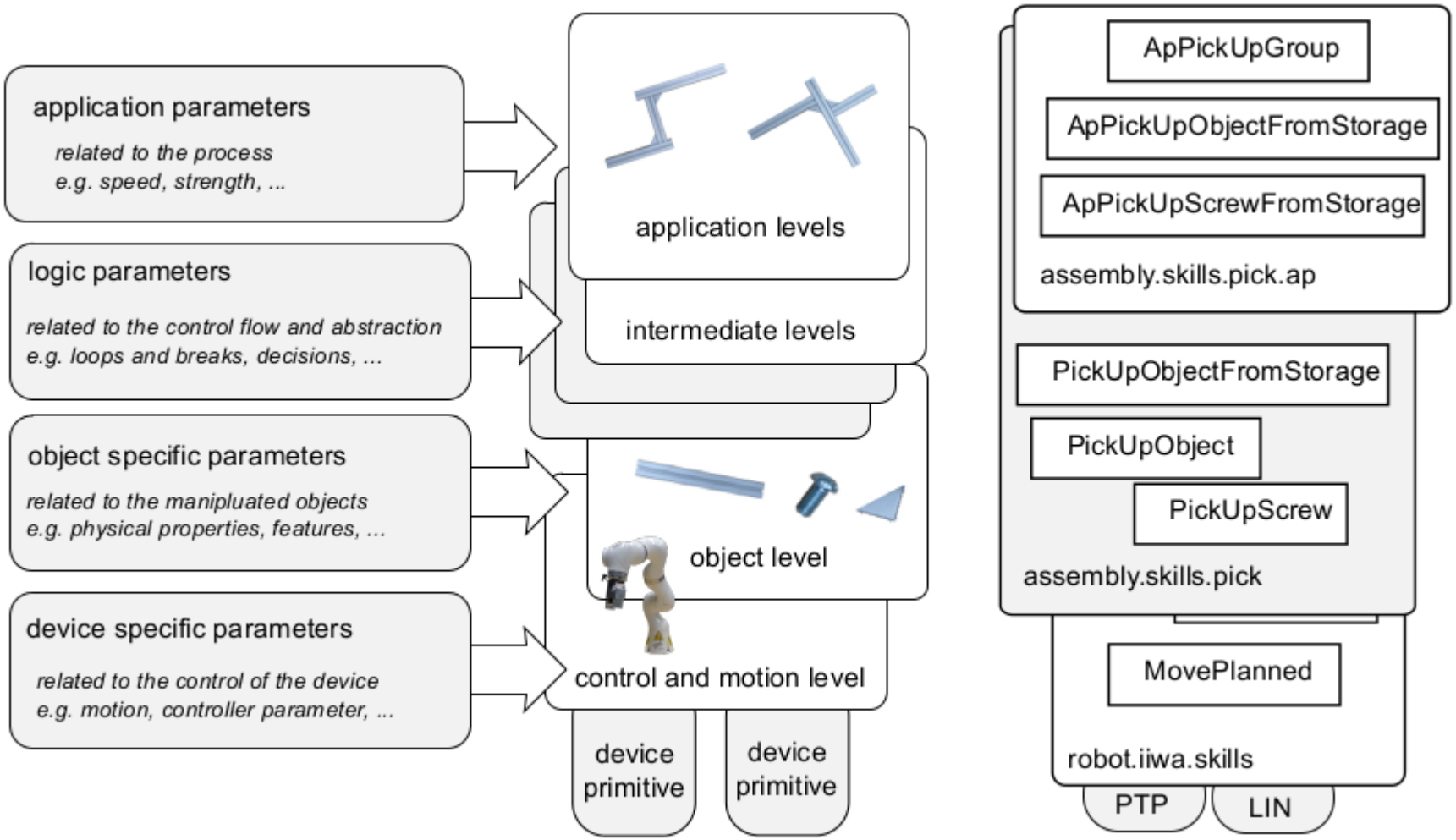
Classification concept



[Nottensteiner, Roa et al., ISR'16]

Skill Library



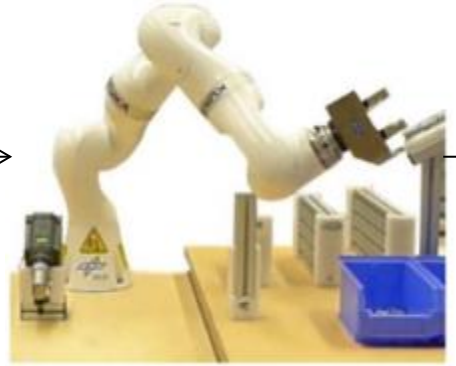
[Nottensteiner, Roa et al., ISR'16]

Exemplary Skill Sequence for the insert_slot_nut Task

Start

PickUpGroupFromStorage

PlacePegInHole



PickUpGroupFromStorage

PlaceSlotNutIntoProfile

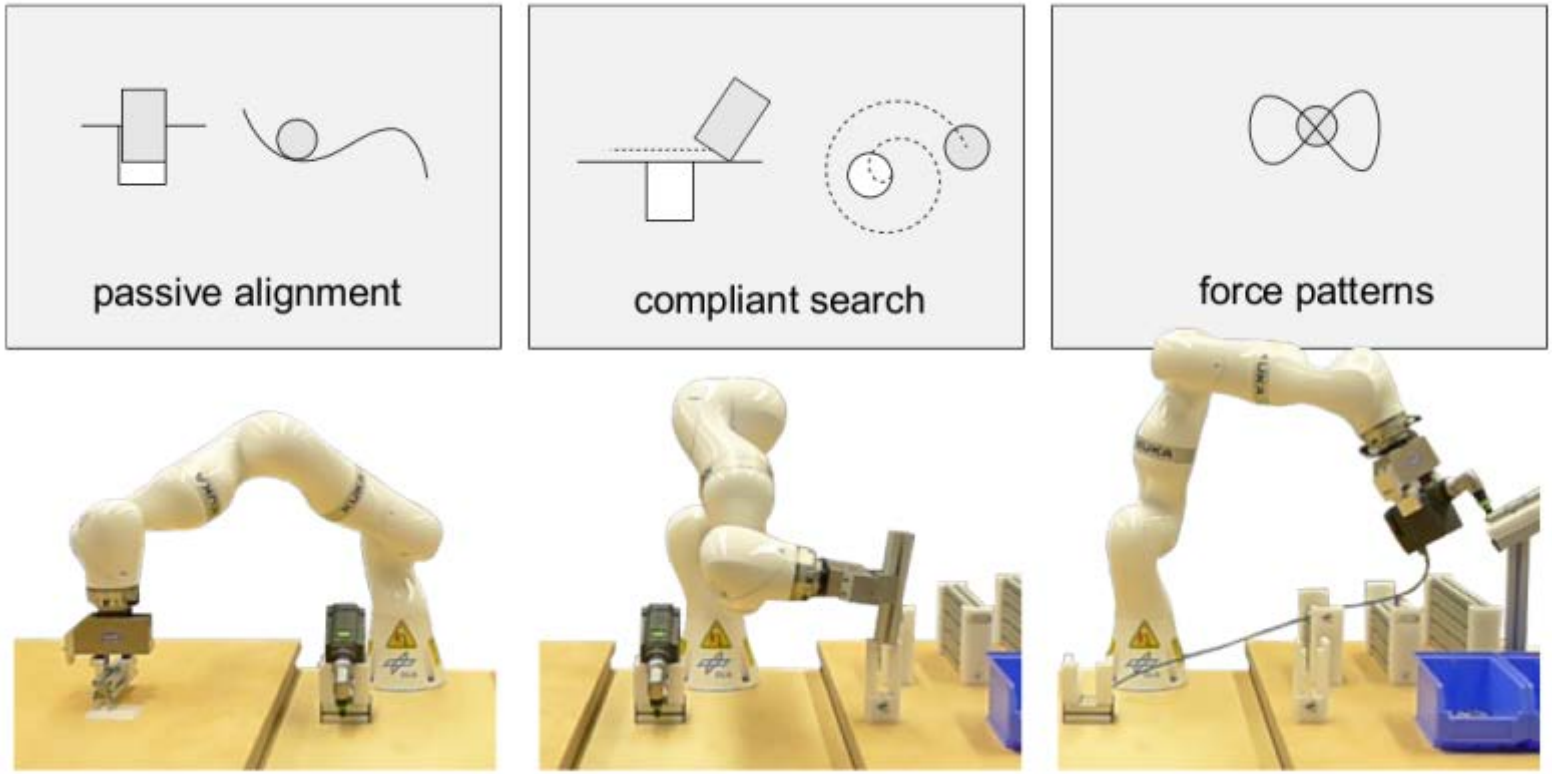
MoveSlotNutIntoProfile

PickUpAndPlaceGroupIn AssemblyFixture.

Finish

[Nottensteiner, Roa et al., ISR'16]

Skill Robustness through Sensor-Based Execution



PlaceObject *PlacePegInHole* *PickUpScrew*

[Nottensteiner, Roa et al., ISR'16]

Assembling one-of-a-kind

SMErobotics at Automatica 2014

https://www.youtube.com/watch?v=2jYhdmk-pMg

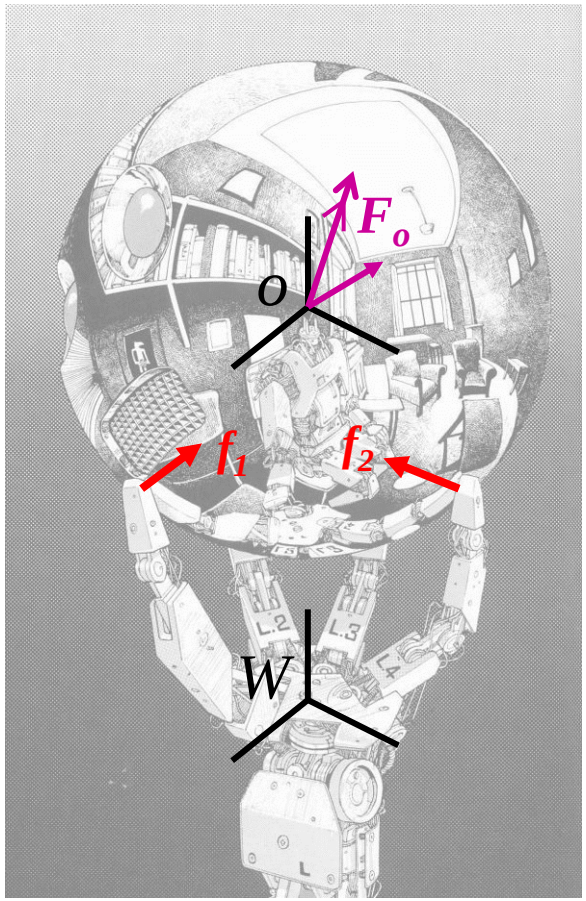
[Nottensteiner, Roa et al., ISR'16]

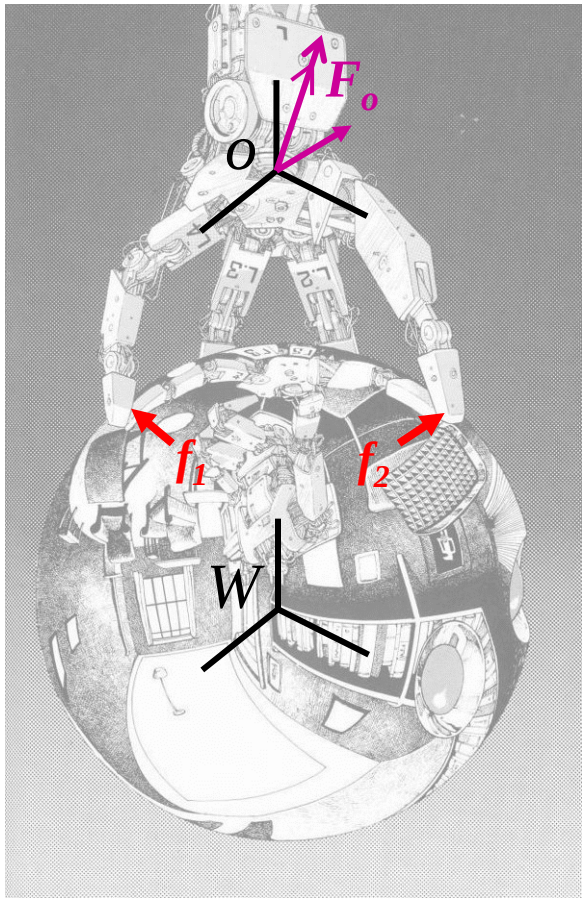
Case 2: Airplane manufacturing

Airplane manufacturing: proof of concept

Comanoid EU project

Grasping and Balancing



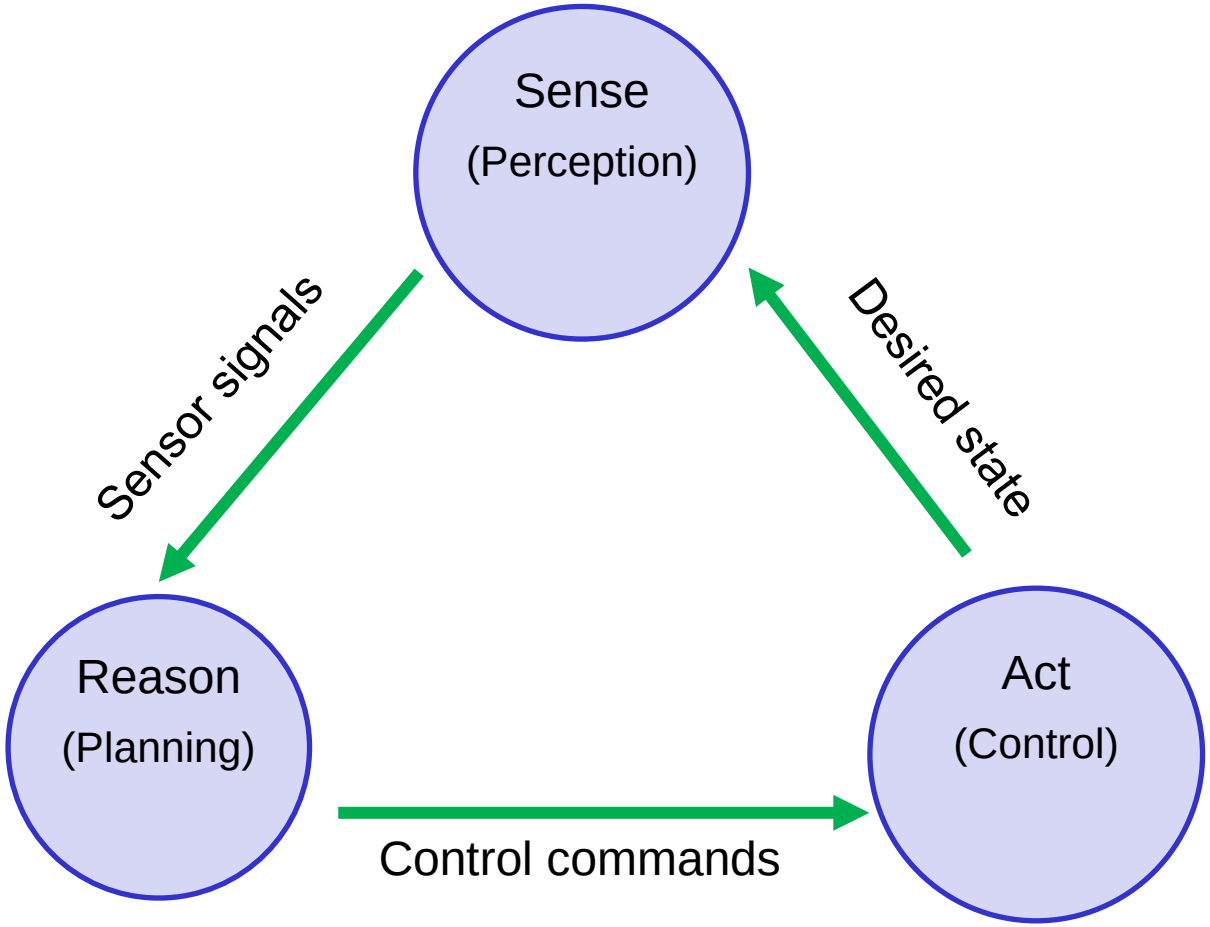


Keypoints

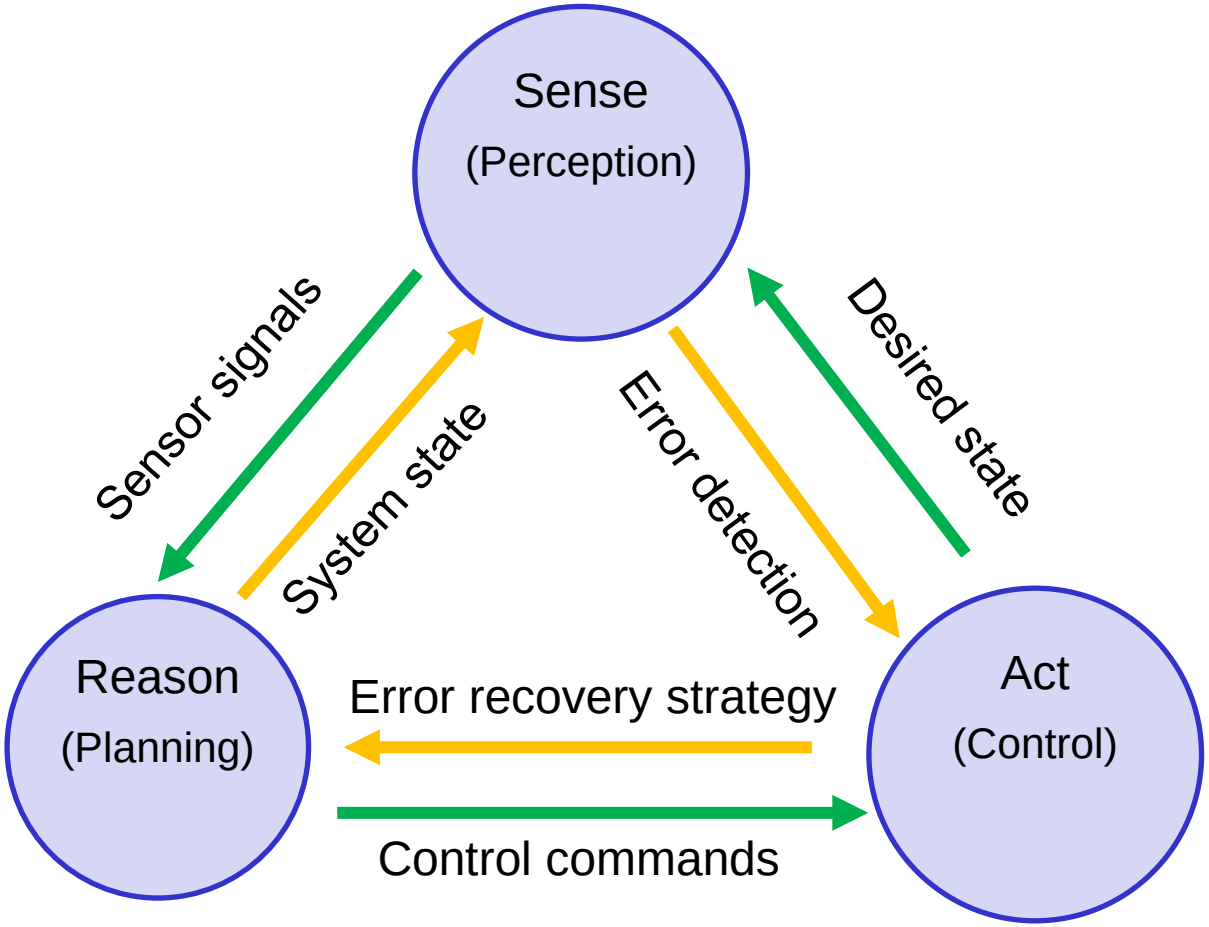
- Real applications require accuracy/robustness/repeatability/…
- Combination of high/medium/low level planning tools allow the automatic generation of complete workflows
- Active compliance provides a nice control framework for robust executions, coping with uncertainties

III. ONE MORE THING….

Action-perception loop



Action-perception loop



Roboception: a DLR Spin-off

roboception

Self-registered 3D-camera

- Real-time capable at high dynamics
- Pose estimation in 6 DoF including velocities
- Direct integration into the control loop for relative navigation, manipulation and grasping
- Real-3D by online fusion of 2.5D data into a 3D point cloud
- Robust against vision drop outs

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Roboception: the sensor

http://www.roboception.de

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http://rmc.dlr.de/rm/en/staff/maximo.roa/publications

Acknowledgments

DLR - Grasping & Manipulation Team: Oliver Porges, Ashok Sundaram, Igor Menkorwski, Dr. Katharina Hertkorn

Roboception – Industrial Application Team: Monika Florek, Dr. Christian Emmerich, Elena Gambaro

DLR: Dr. Christian Ott, Alexander Werner, Bernd Henze, Johannes Englsberger, Werner Friedl, Dr. Tim Bodenmüller, Andreas Stemmer, Korbinian Nottensteiner, Dr. Neal Lii, Dr. Zhaopeng Chen, Dr. Hannes Höppner, Dr. Markus Grebenstein

Roboception: Dr. Michael Suppa, Dr. Heiko Hirschmüller, Dr. Korbinian Schmidt

Other places: Dr. Ulrike Thomas (TUC), Dr. Uwe Zimmermann (KUKA), Christoph Borst (KUKA)

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