A dual-arm approach for manipulation of articulated objects and robotic assembly

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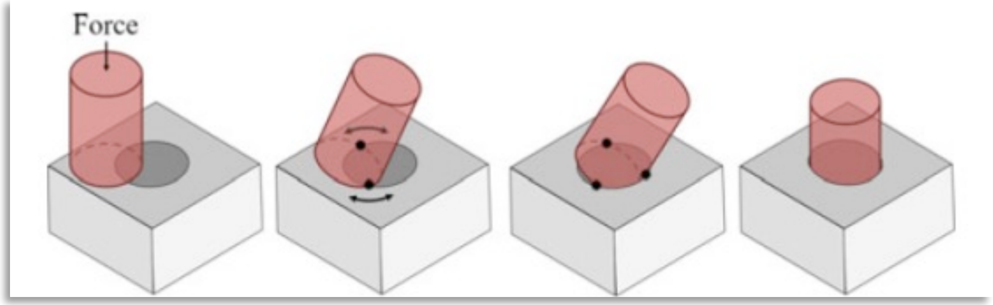
KTH Computer Science
and Communication

Folding assembly: Definitions

- Peg-in-hole insertion
- Threated fastener insertion (Screwing)
- Bolt and nut
- Snap-fit
- Insertion via deformation
- Folding



H. Park et. al, Transactions of Industrial Electronics 2017, VOL. 64, NO. 8

E.J. Nicolson & R.S. Fearing, ICRA93

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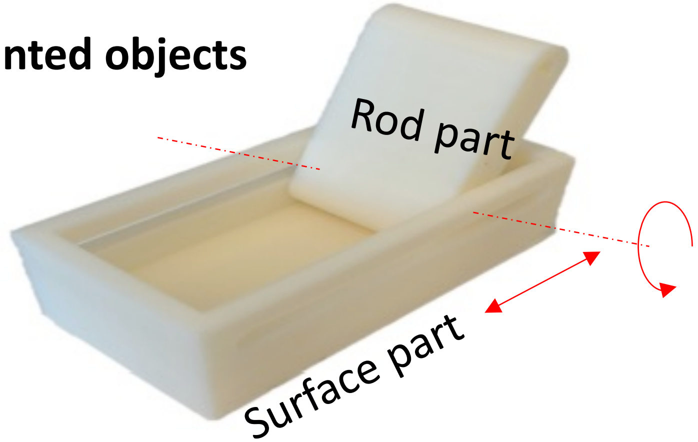
Folding assembly: Examples

SARAFun Folding Assembly

3-d printed objects



General folding -- illustration

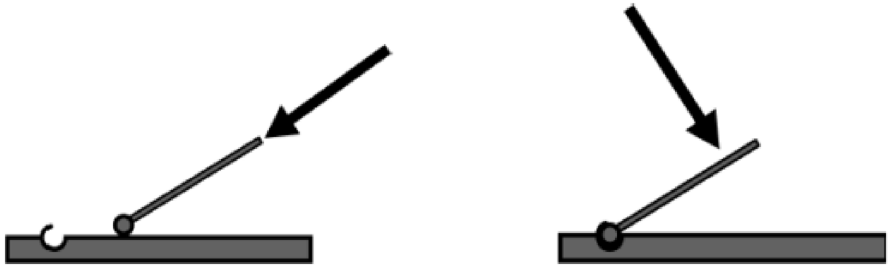
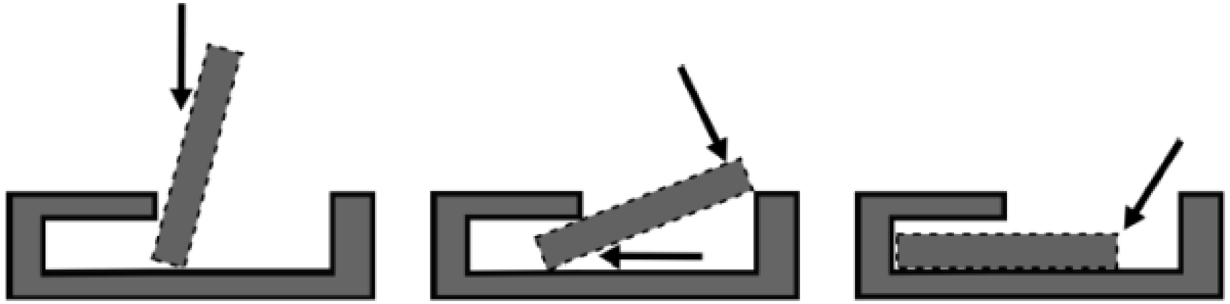
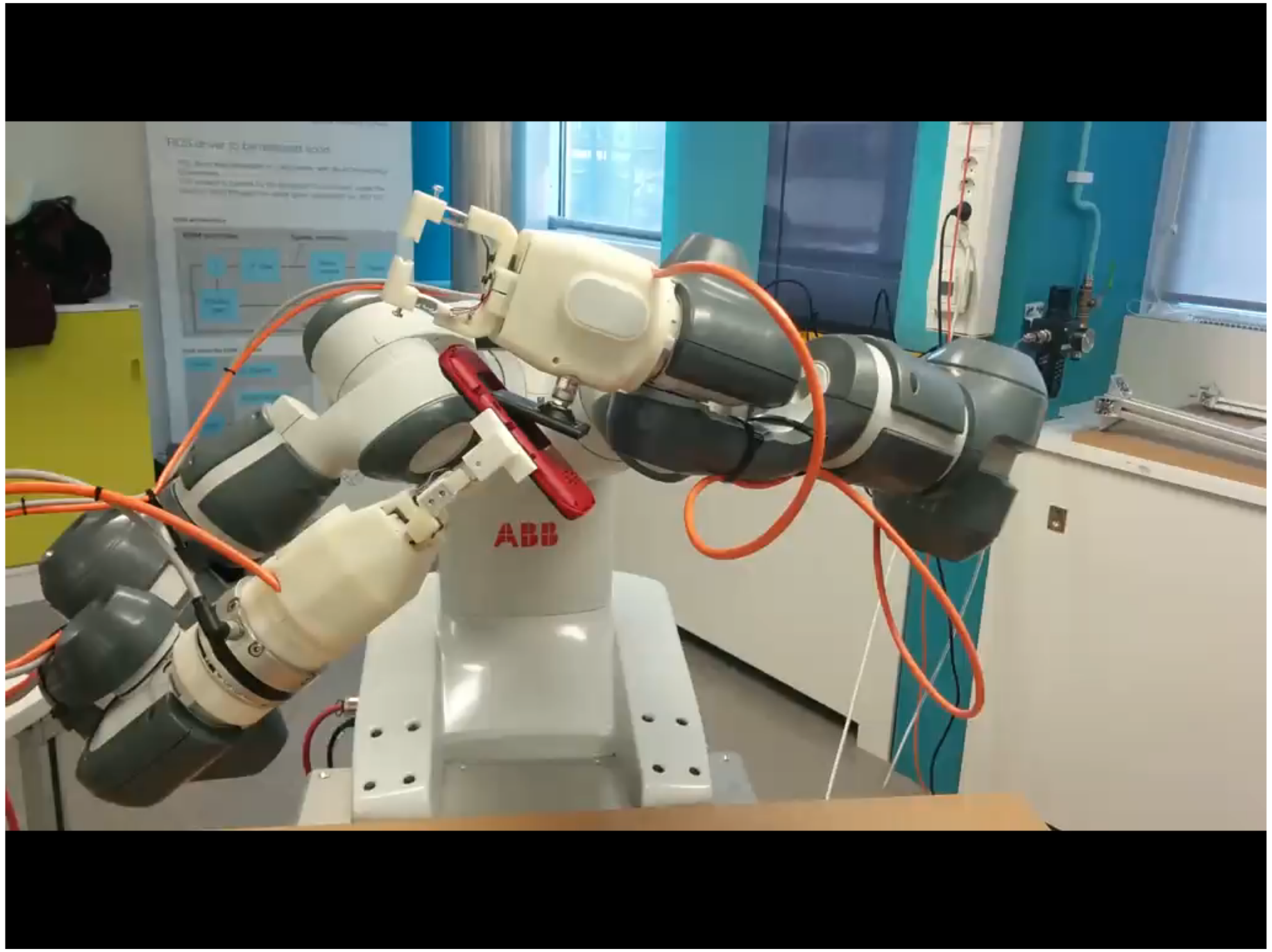


Illustration of battery insertion

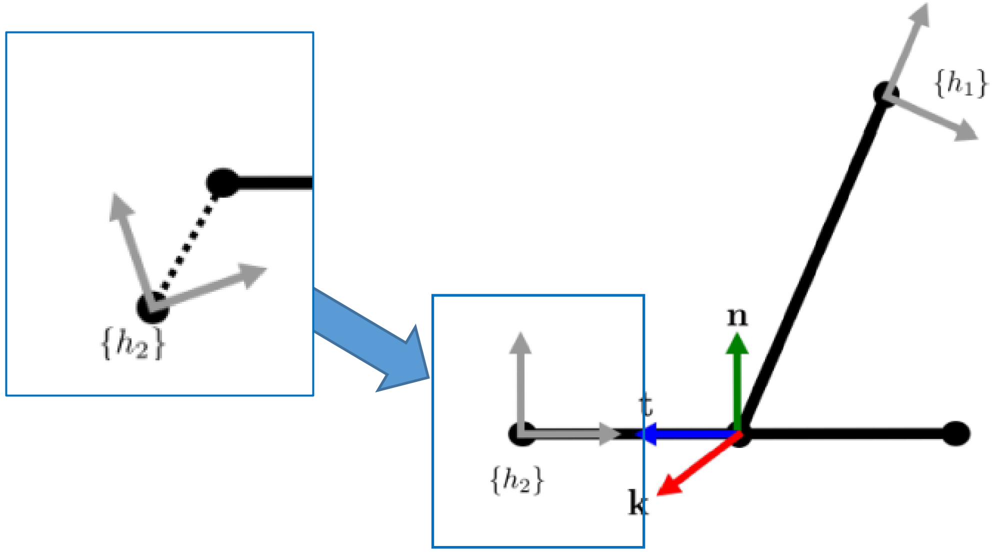


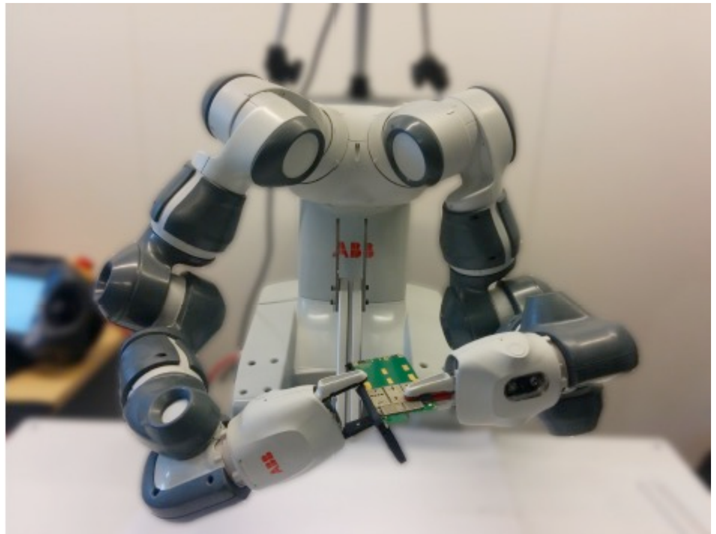
Folding assembly: Examples

Folding assembly: demonstration with dual arm robot



Uncertainties in folding assembly





- **Uncertainties:**
  - Grasp pose
  - Contact point
- **Bimanual Robots:**
  - Flexibility – Redundancy
  - Allows for better exploitation of proprioception force/torque based perception

A 2 DOF mechanism kinematic model

- Pliers, scissors, drawers, etc. are mechanisms
- Assembly tasks can be modelled as mechanisms

"Sliding" velocity

Kinematics

$$\boldsymbol{v}_s = -\mathbf{r}_1 \times \boldsymbol{\omega}_1 + \mathbf{r}_2 \times \boldsymbol{\omega}_2 + \dot{\mathbf{p}}_1 - \dot{\mathbf{p}}_2$$

$$\boldsymbol{\omega}_r = \boldsymbol{\omega}_2 - \boldsymbol{\omega}_1$$

Relative angular velocity

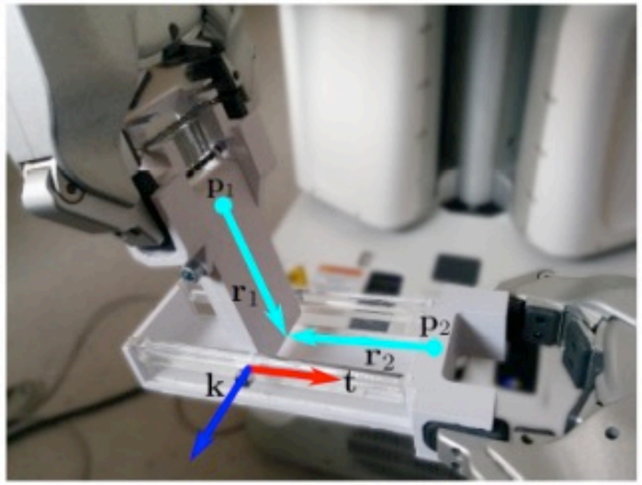
Velocity constraints

Statics

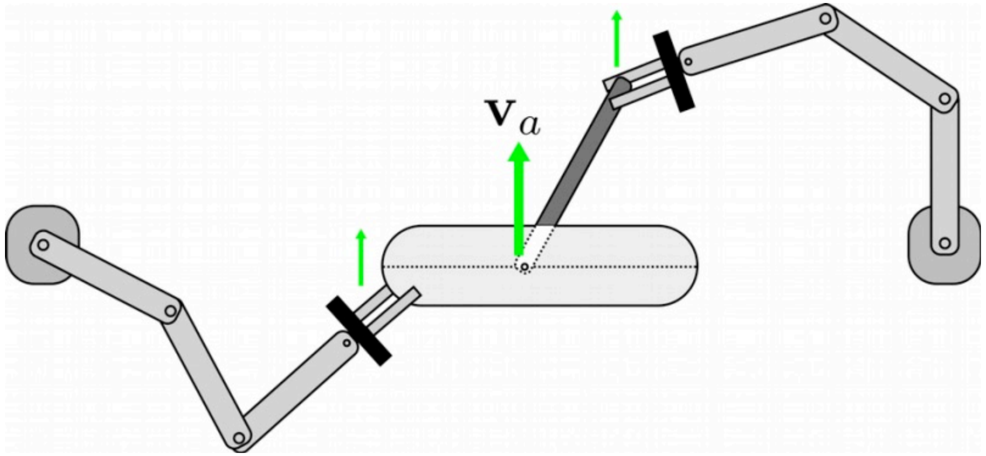
$$\begin{cases} (\mathbf{I}_3 - \mathbf{t}\mathbf{t}^\top)\boldsymbol{v}_s = \mathbf{0} \\ (\mathbf{I}_3 - \mathbf{k}\mathbf{k}^\top)\boldsymbol{\omega}_r = \mathbf{0} \end{cases}$$

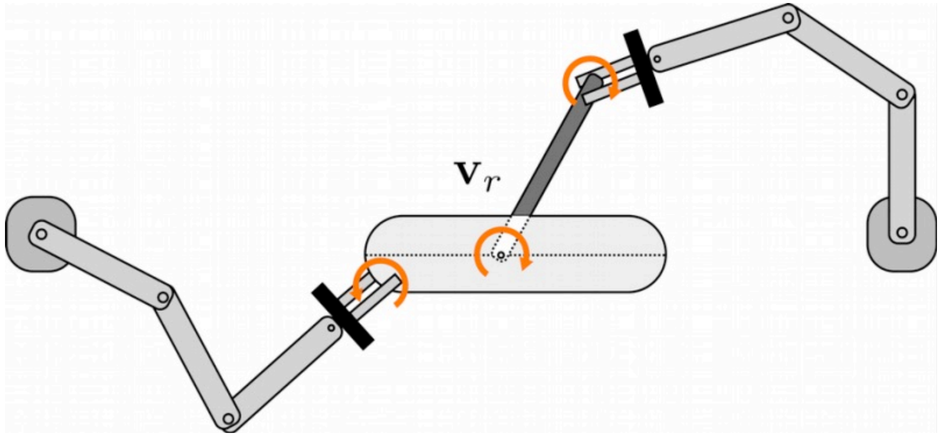
$$\boldsymbol{\tau}_i = \mathbf{r}_i \times \mathbf{f}_i$$

Force torque relationship



Dual Arm Formulation – Extended Cooperative Task Space





Absolute motion twist

Linking

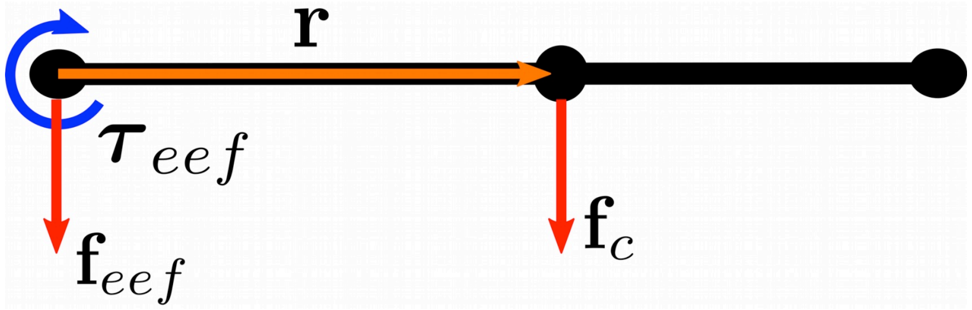
$$\mathbf{v}_E = \begin{bmatrix}\mathbf{v}_a\\ \mathbf{v}_r\end{bmatrix} \in \mathbb{R}^{12} \longrightarrow \mathbf{v}_E = \mathbf{L}(\alpha)\mathbf{W}\begin{bmatrix}\mathbf{v}_1\\ \mathbf{v}_2\end{bmatrix} \longrightarrow \mathbf{v}_E = \mathbf{J}_E\dot{\mathbf{q}}$$

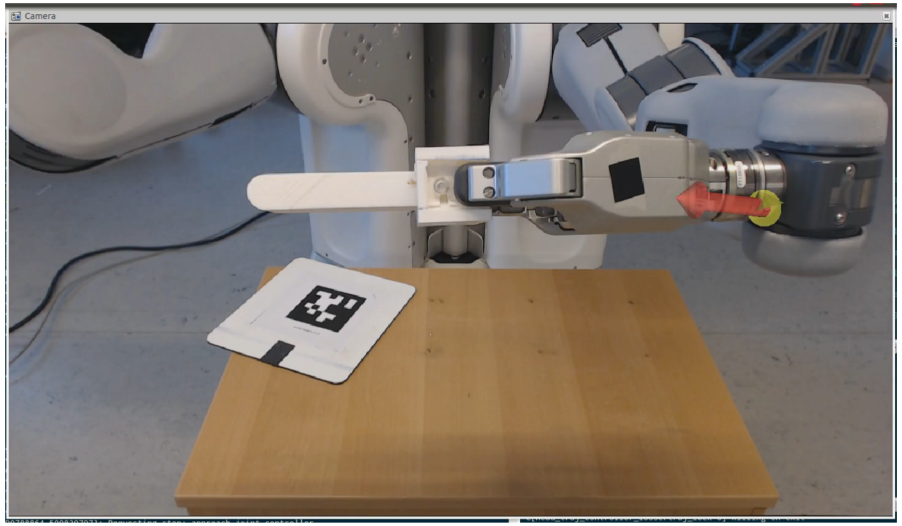
Convert to grasp

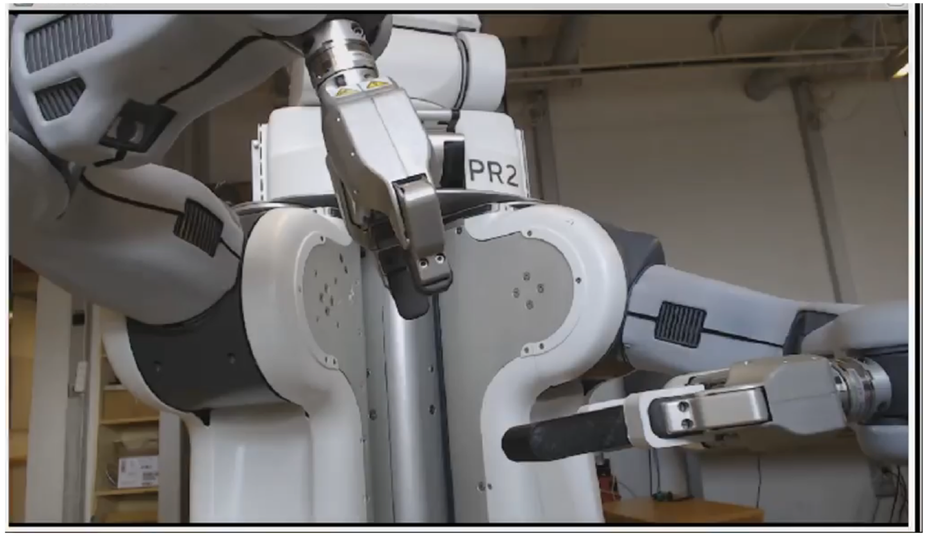
Determines the task-load for each end-effector

Extreme cases: only one end-effector is moving

Contact point estimation:

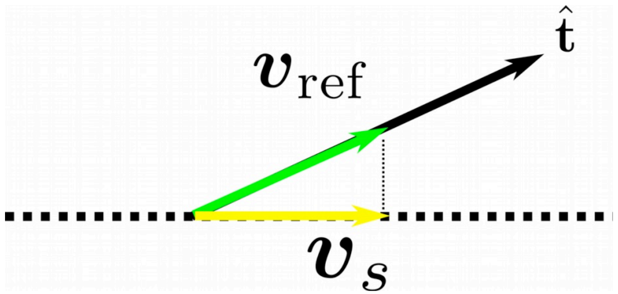


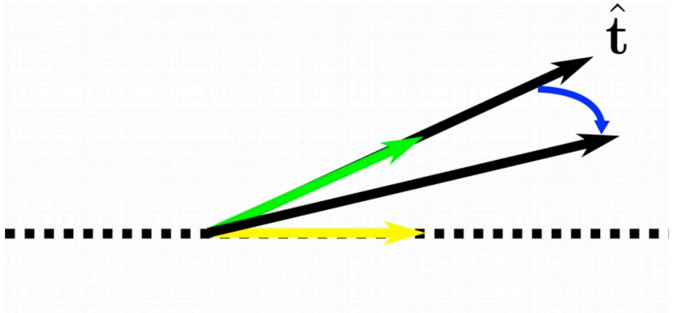




Kinesthetic Perception

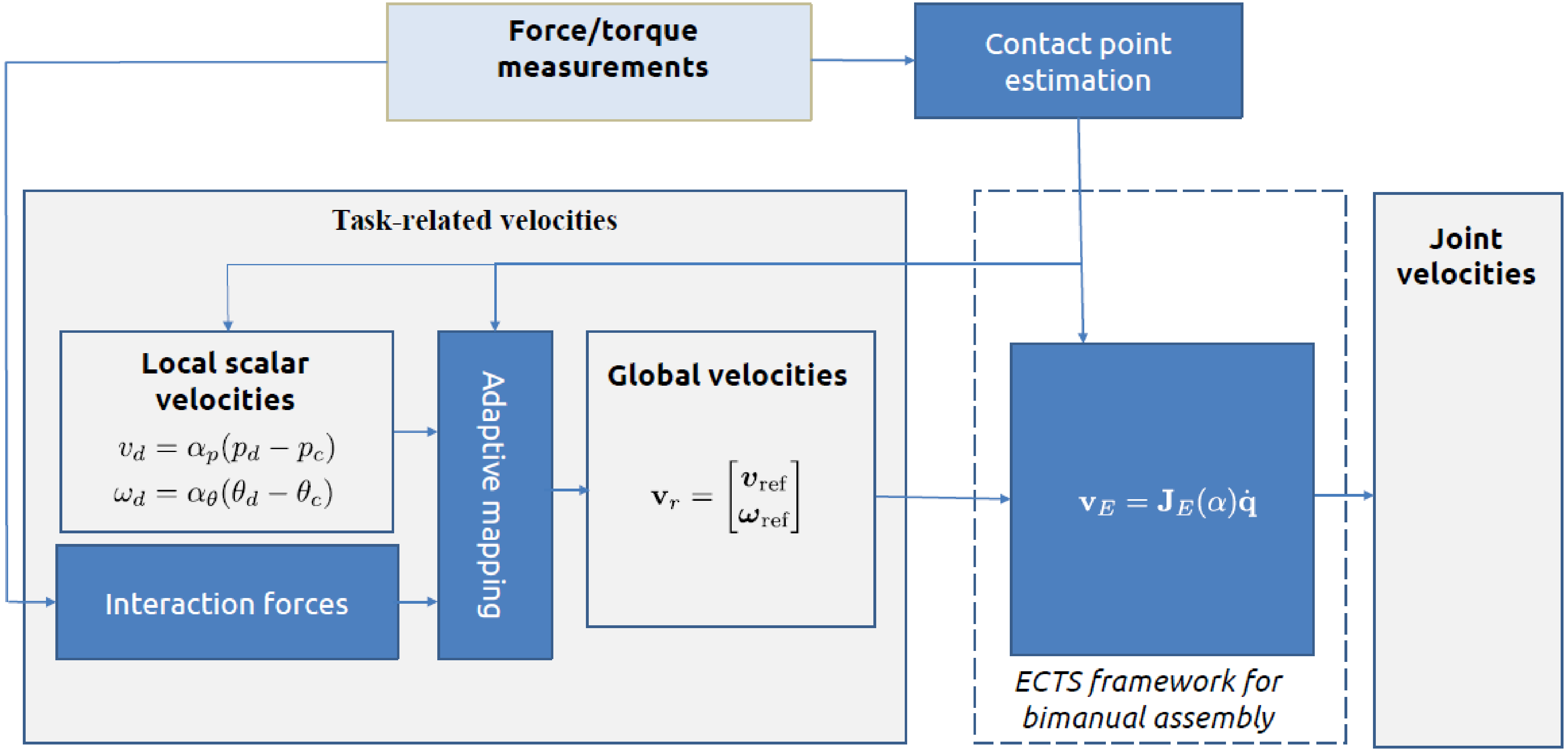
Adaptive mappings for “joint”-axes identification



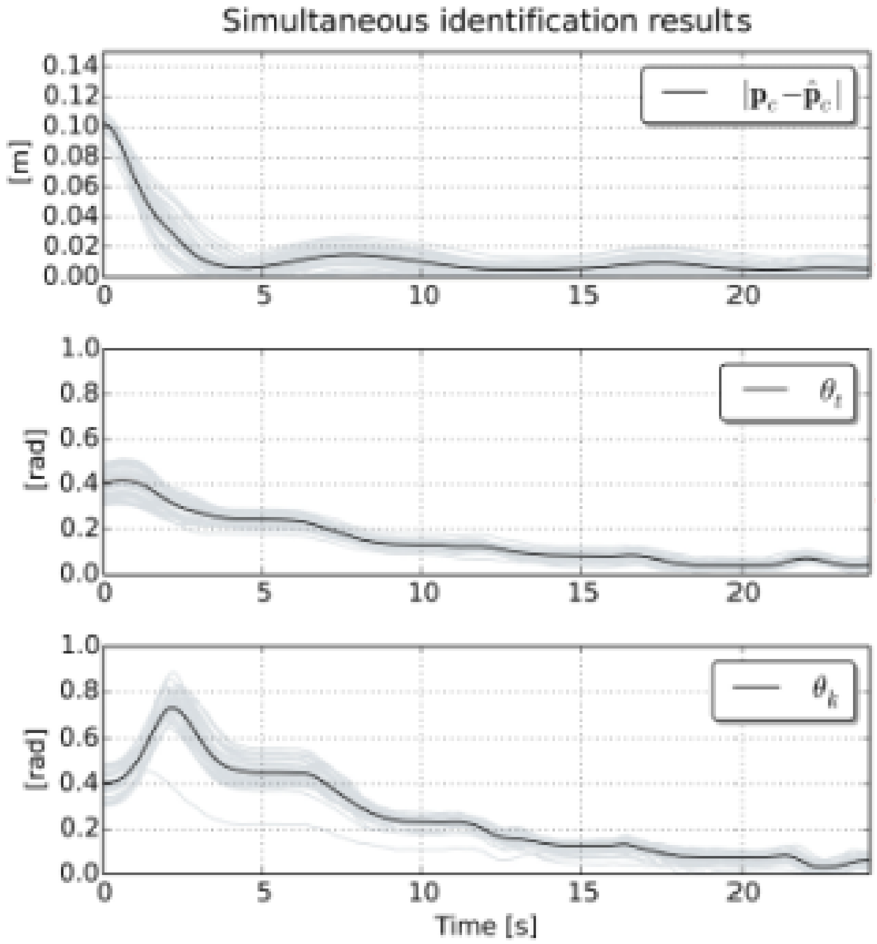


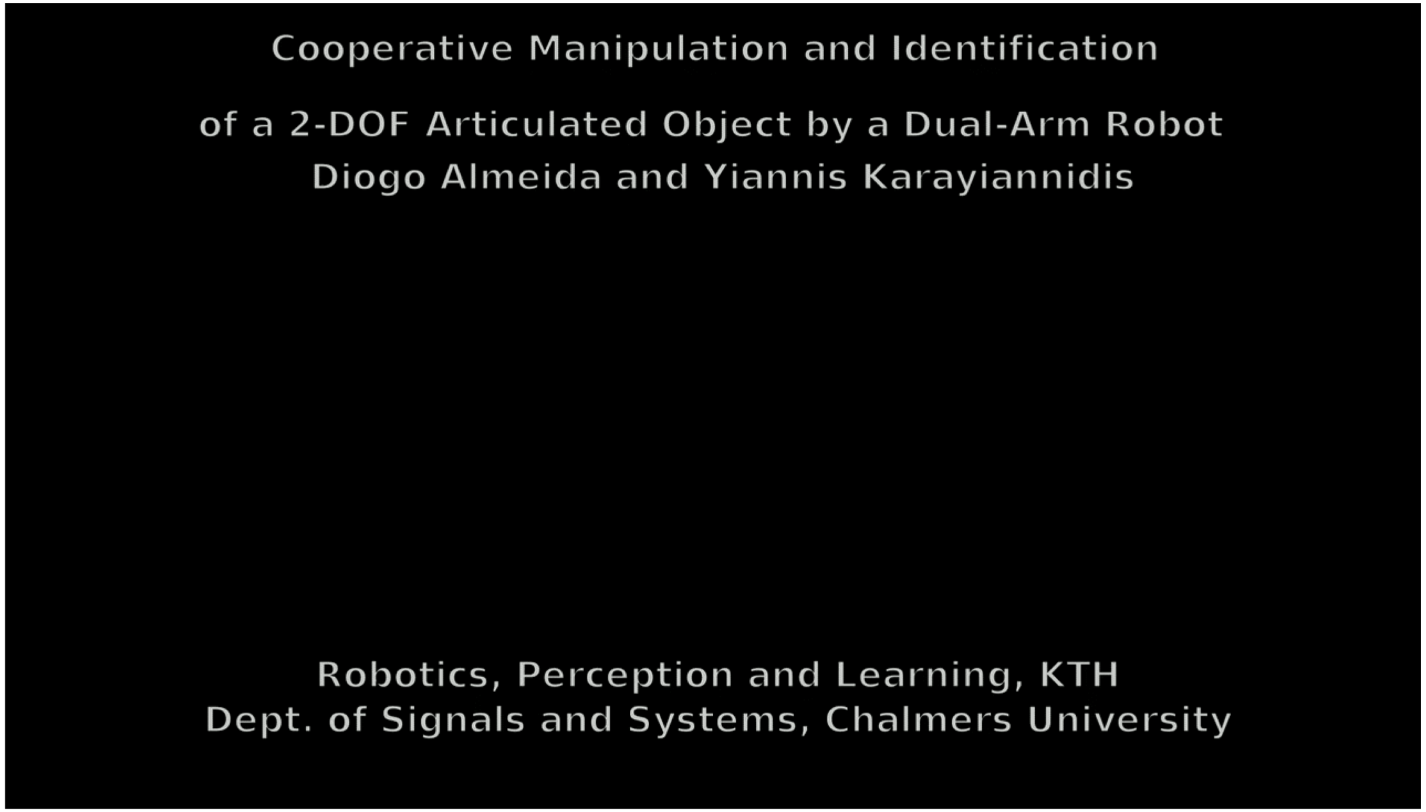
- The control inputs (velocities) are designed based on online estimates and force feedback

Proposed framework



Results

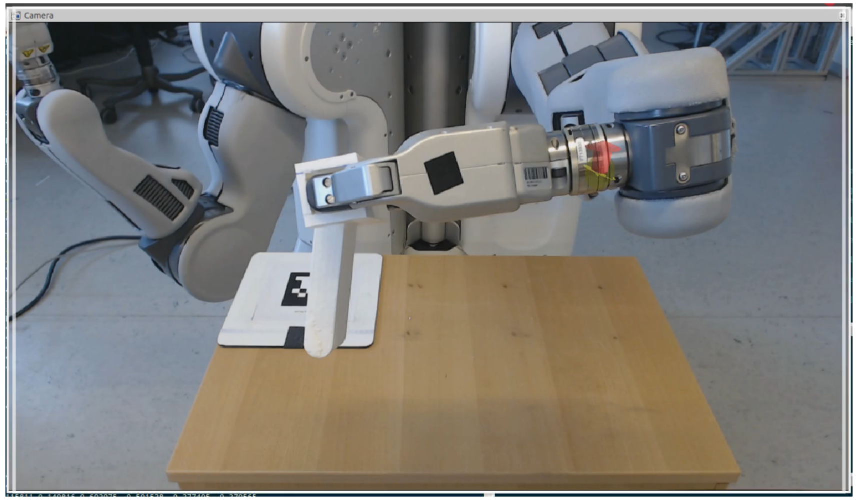




Almeida, Karayiannidis, ICRA2018, video

Future work

- Force/torque based perception for imperfect situations:
  - Non-rigid grasps
  - Contacts that exert torques
- Exploit both sensors



- Automatic role allocation
- Efficient redundancy exploitation

Linking

$$\mathbf{v}_E = \mathbf{L}(\alpha)\mathbf{W}\begin{bmatrix}\mathbf{v}_1 \\ \mathbf{v}_2\end{bmatrix}$$

Convert to grasp

Thank you!

ABB Sweden

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Centre for Research and Technology Hellas

Bielefeld University

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Vetenskapsrådet

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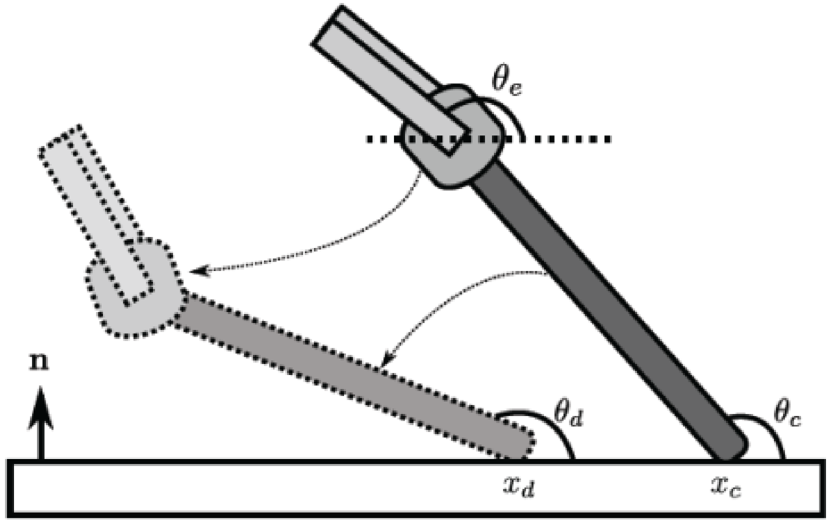
Current work: Compliant Grasp for assembly

- Allows for in-hand motion of the object

  Reduce motion of the arm
- Allows for the hand performing the assembly to estimate the state of the grasped object
- Allows for moving both arms

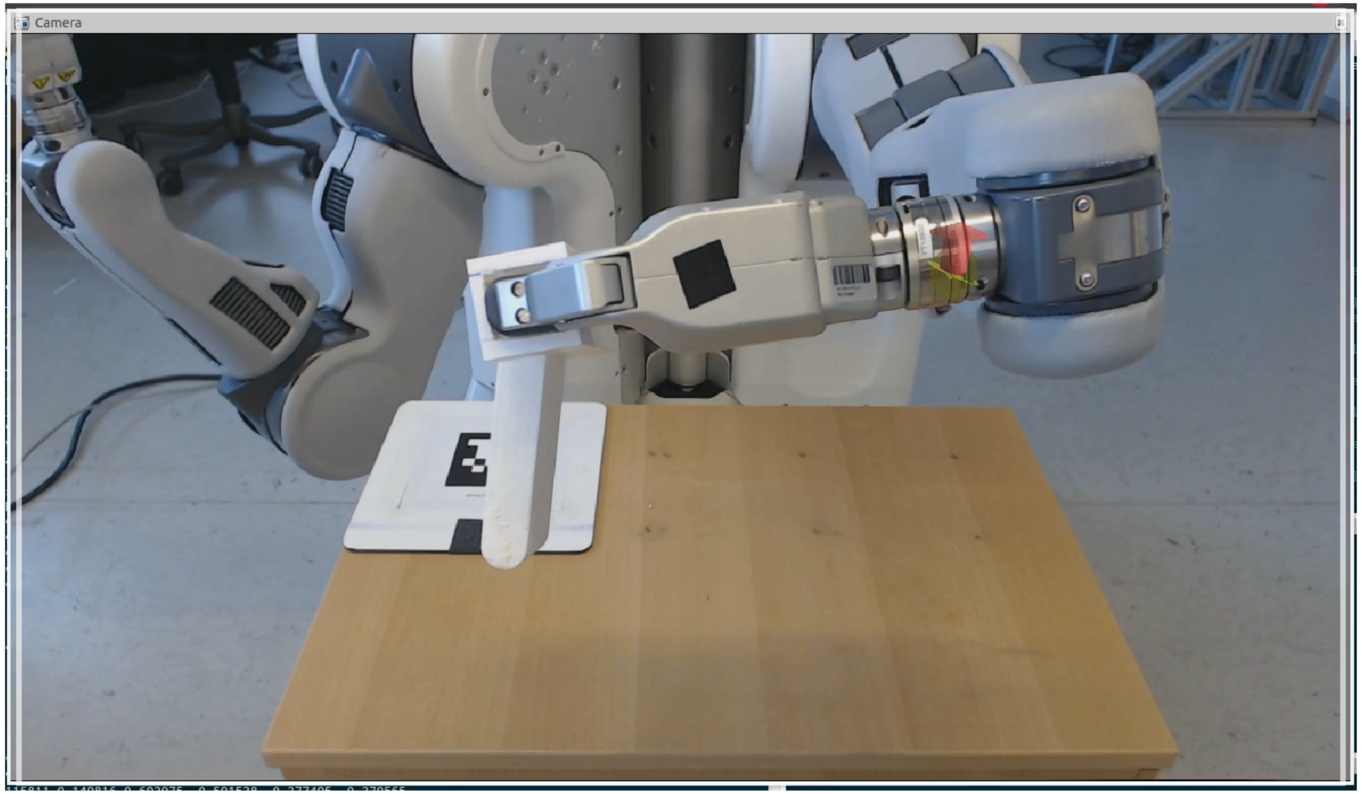


$$\dot{\mathbf{p}}_e = [\, \mathbf{I}_2 \quad \mathbf{s}(\mathbf{r}) \,] \begin{bmatrix} \dot{\mathbf{p}}_c \\ \dot{\theta}_c \end{bmatrix}$$ → **Process model**

$$\tau_e = \mathbf{s}(\mathbf{r})^\top \mathbf{f}_c$$ → **Observation model**

$$\tau_e = K_s(\Theta_o - \theta_s)$$

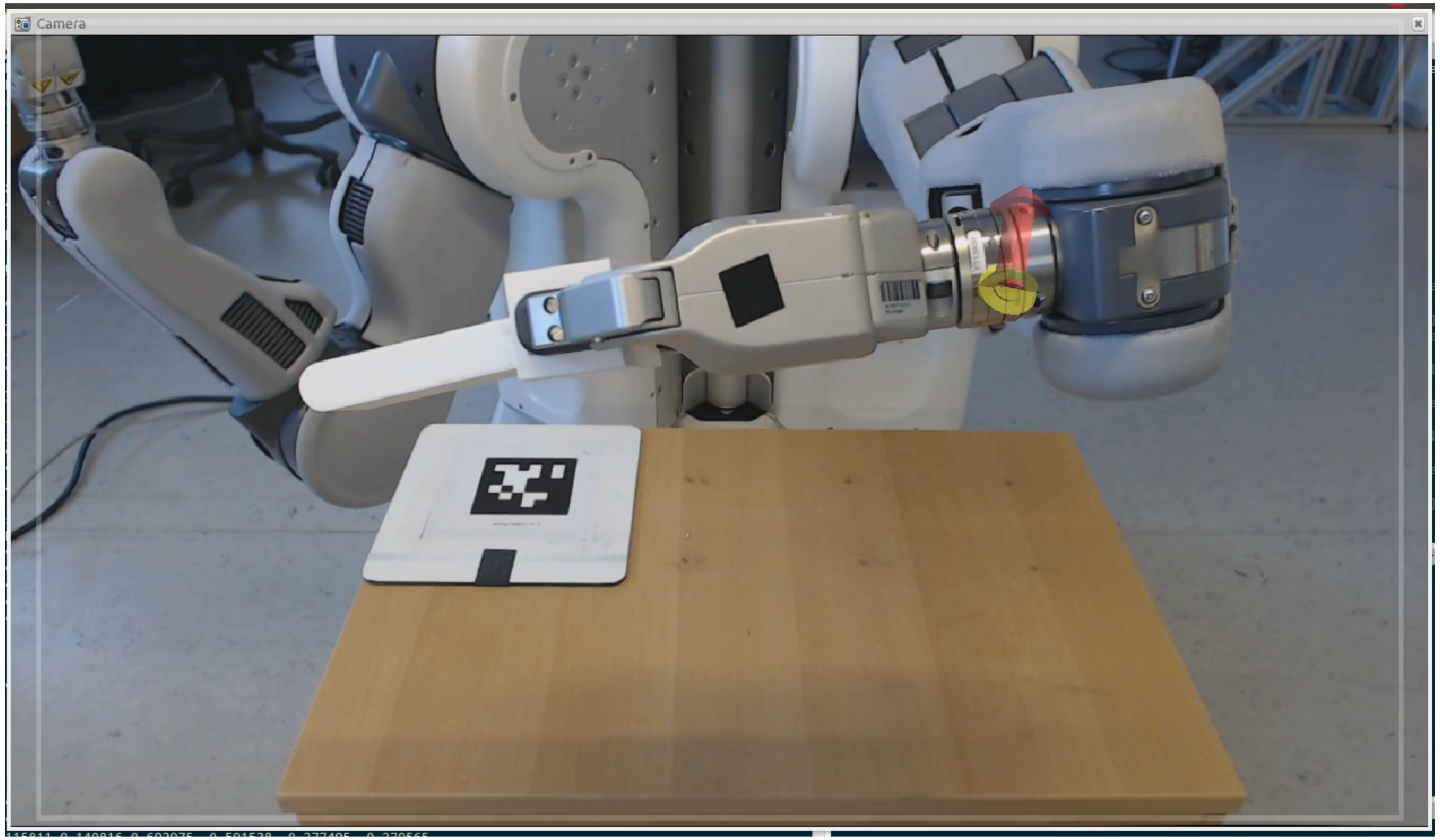
Passive joint Grasp - Wrenches



Passive joint

Unclear wrench signals

Current work: Compliant grasp - Wrenches

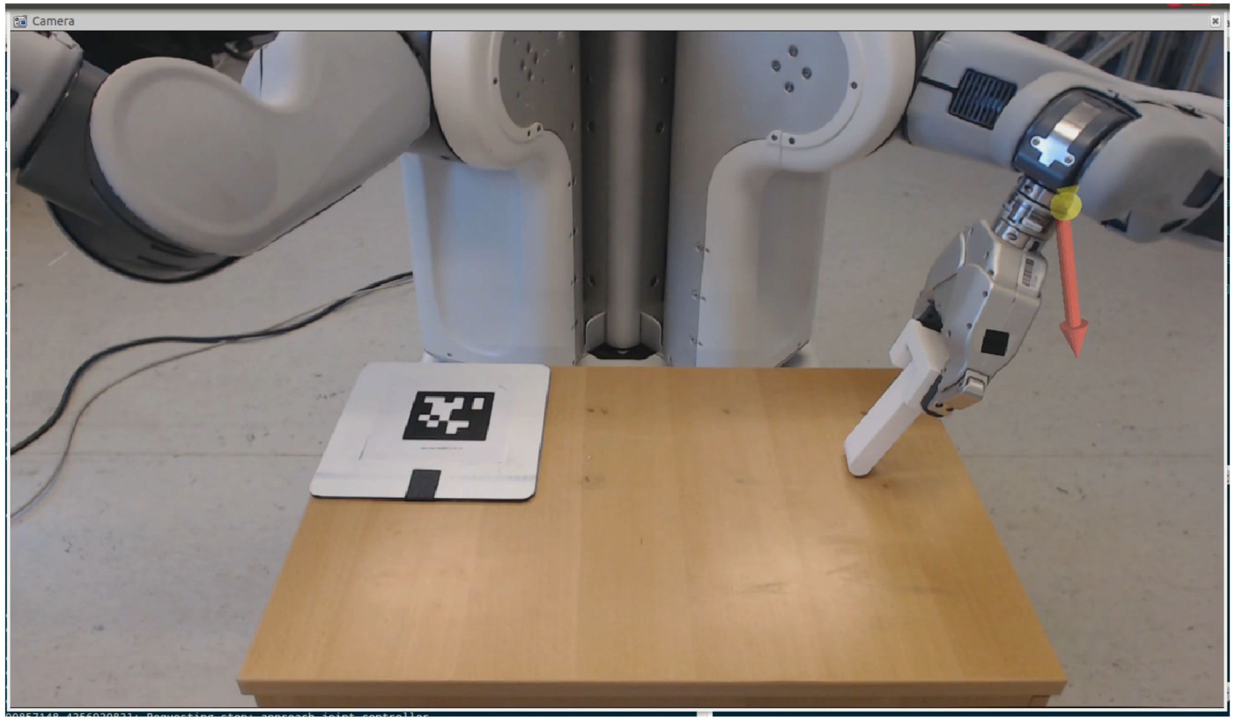


Compliant grasp

Clear wrench signals

Current work: Experiments with compliant grasps

Force control



Pivot