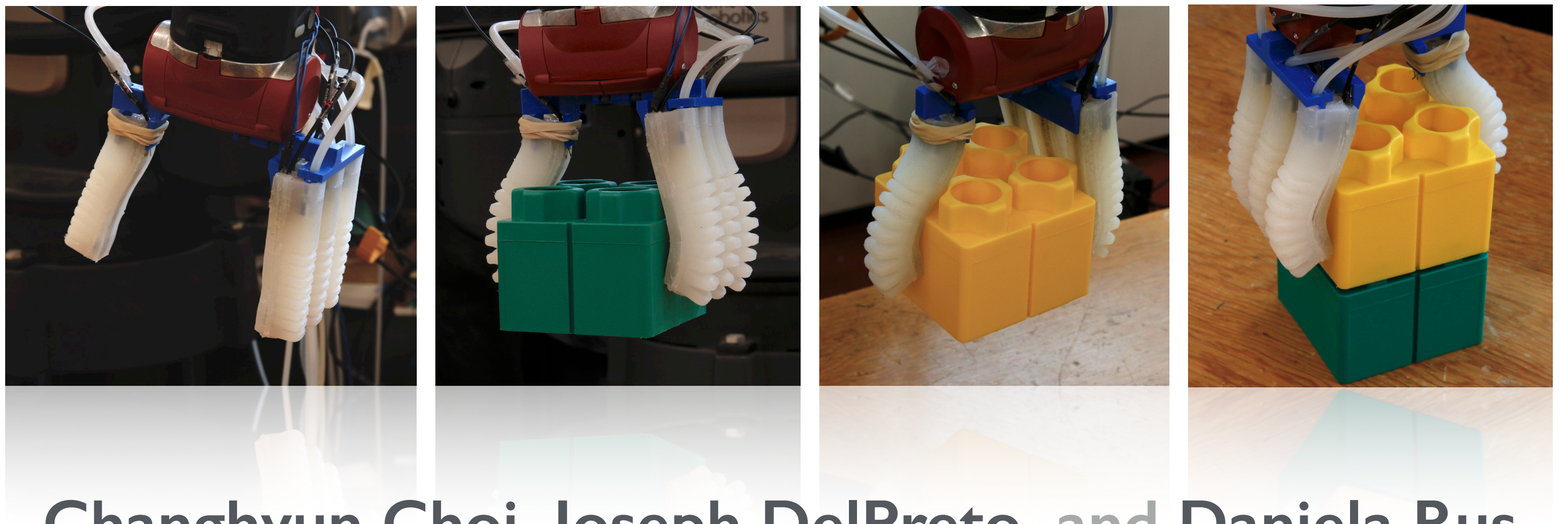
Using Vision for Pre- and Post-grasping Object Localization for Soft Hands



Changhyun Choi, **Joseph DelPreto**, and **Daniela Rus**

Computer Science & Artificial Intelligence Laboratory

Massachusetts Institute of Technology

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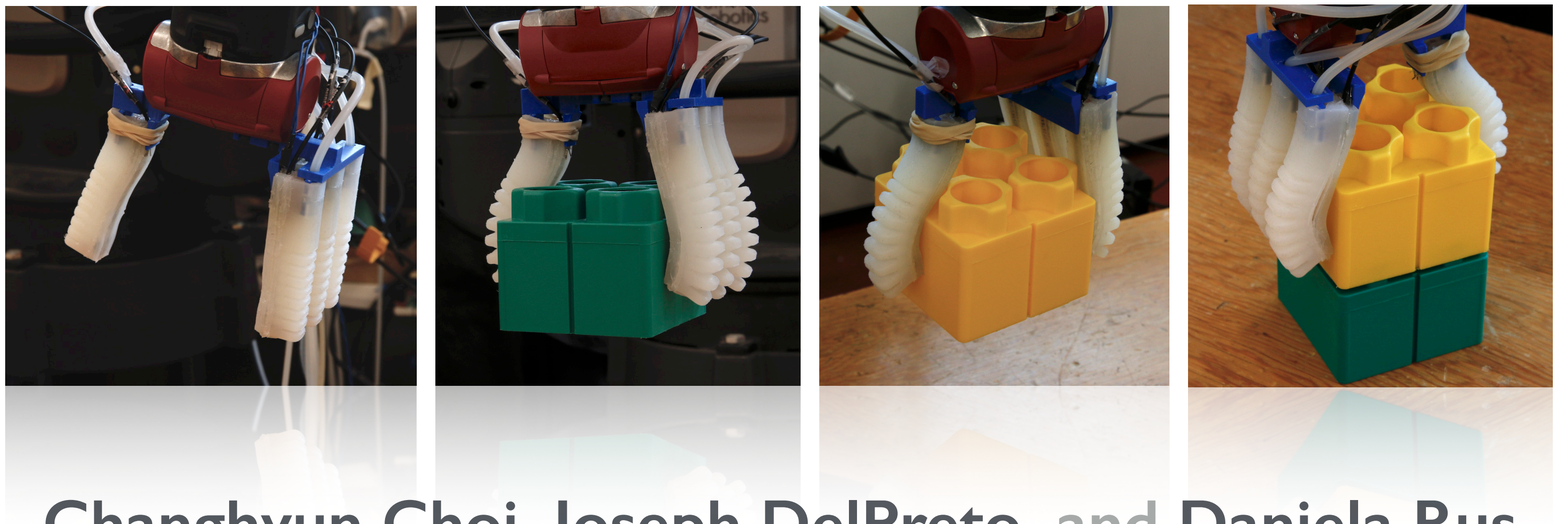

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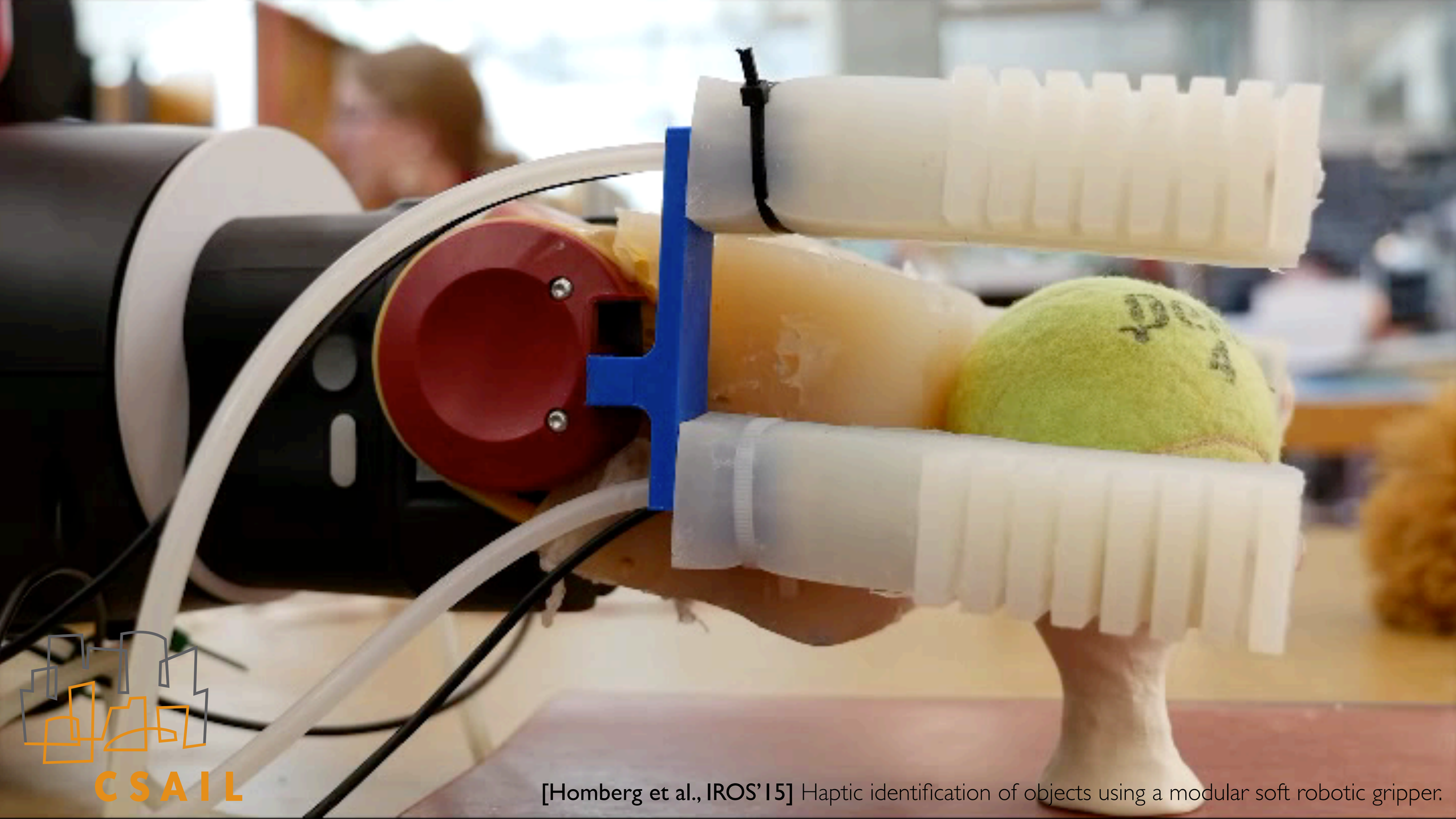

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[Homberg et al., IROS'15] Haptic identification of objects using a modular soft robotic gripper.


rethink robotics
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Introduction

- Soft hands allow **compliance** and **adaptability**.
- They increase **uncertainty** of the object pose after grasping.

Visual sensing *ameliorates* the increased uncertainty!

- How can we **reduce** the post-grasping uncertainty of object pose?
- How do we enable **soft hands** to perform **advanced manipulation** which requires precise object pose?

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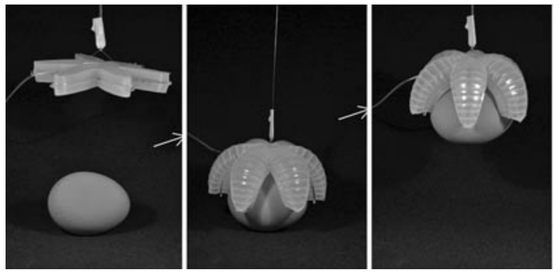
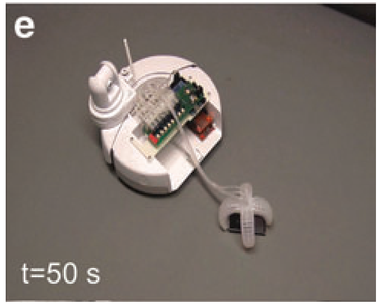
Related Work

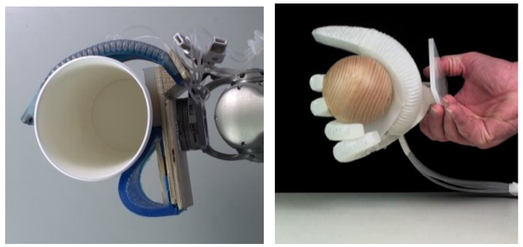
Jamming Gripper
Brown et al., PNAS'10



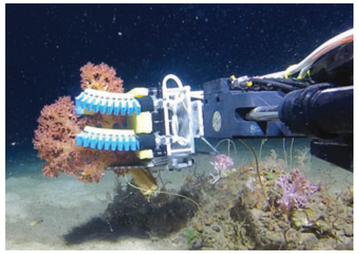
Starfish-shaped Gripper
Ilievski et al., Angewandte Chemie'11



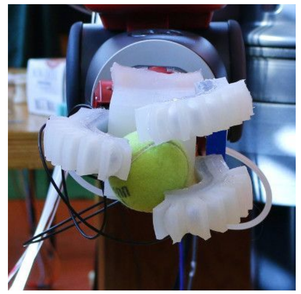
Quadruped Gripper
Stokes et al., SoRo'14



Multi-finger Soft Hands
Deimel & Brock, ICRA'13 & IJRR'16



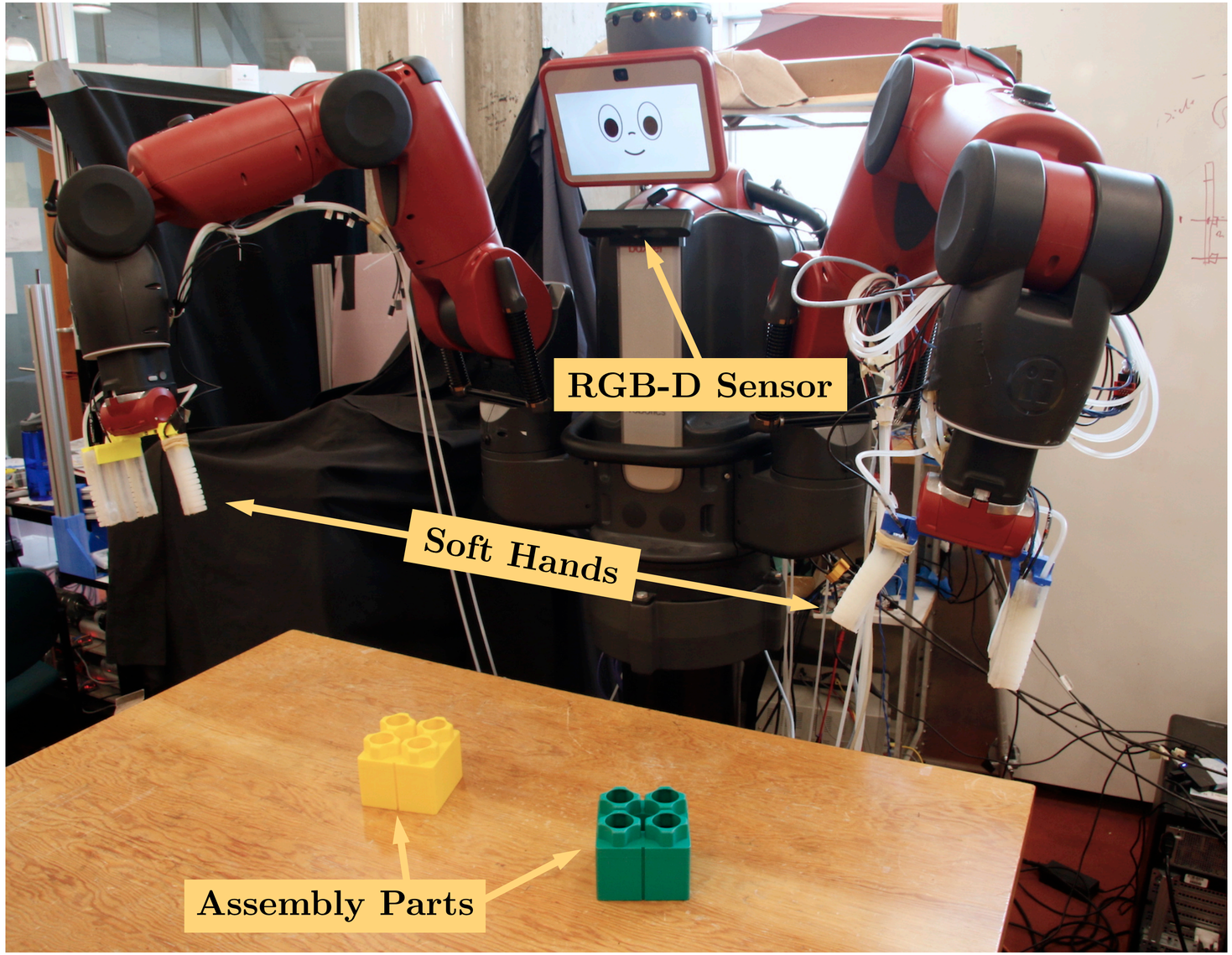
Multi-finger Soft Hands
Galloway et al., SoRo'16



Multi-finger Soft Hands
Homberg et al., IROS'15

- Closing loop between *soft manipulation* and *visual perception* has been less addressed.
- We employ an RGB-D vision to go **beyond simple grasping** and to enable soft hands to do **advanced object manipulation.**

System Overview



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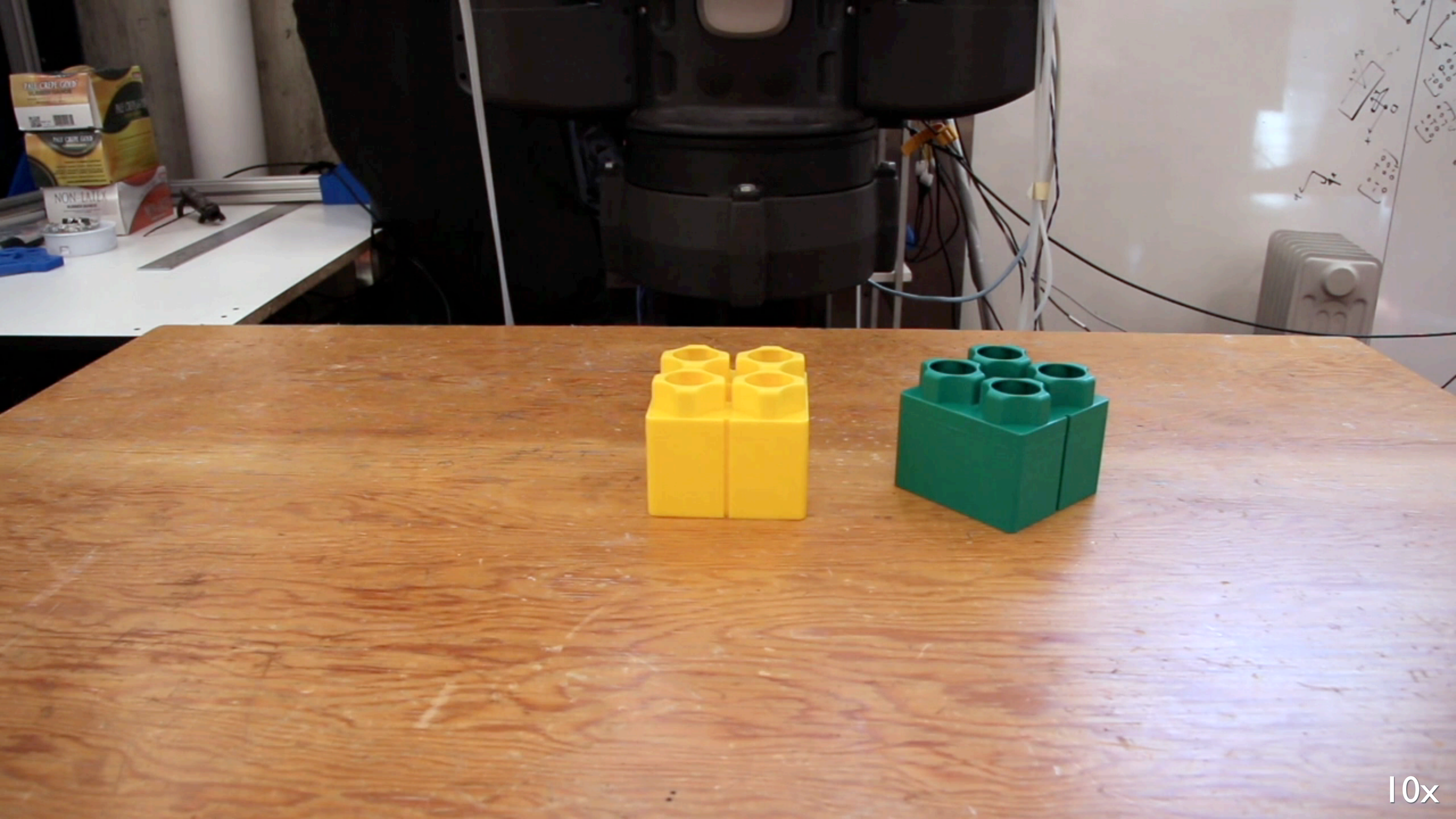
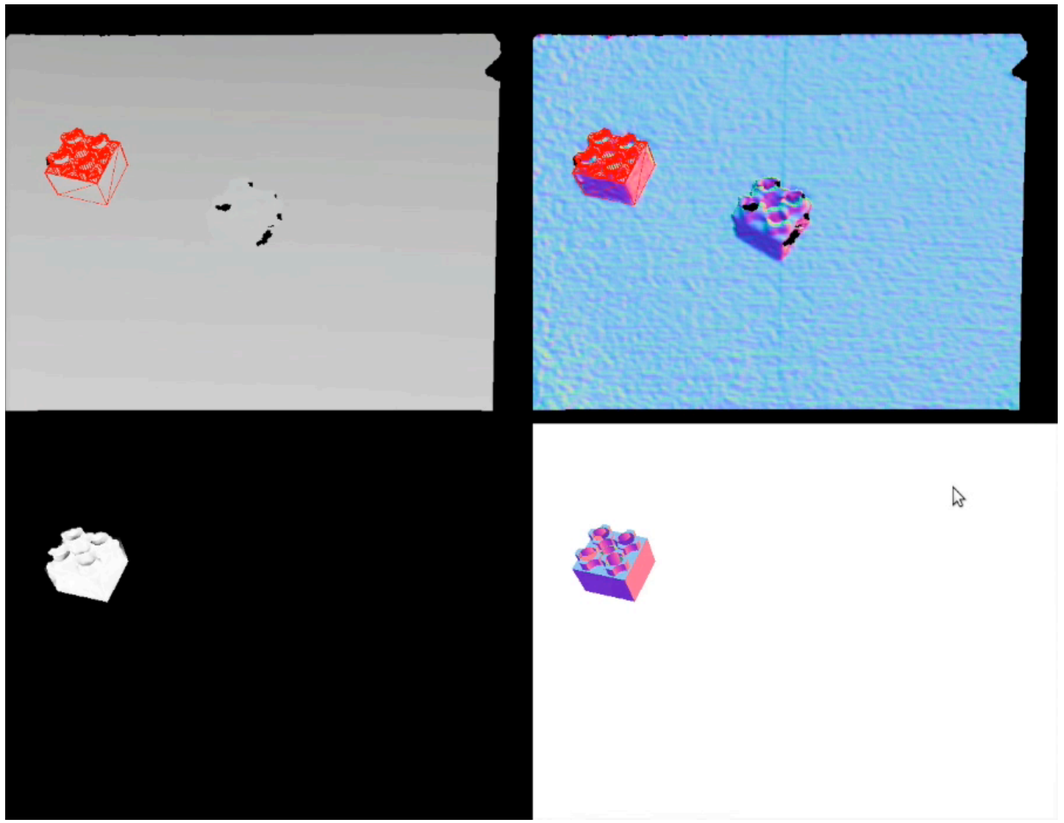

10x

Pre-grasping Object Localization

Goal: To estimate the 6-DOF **pose** of each object on a table



- Planar segmentation (table-top assumption)
- For each foreground object point cloud
  - center location $\mathbf{t} \in \mathbb{R}^3$
  - a set of rotations (in-plane) $\mathbf{R}_i \in \mathcal{R} \subset SO(3)$
- An ICP algorithm is initialized
- The maximum likelihood pose is chosen for each object

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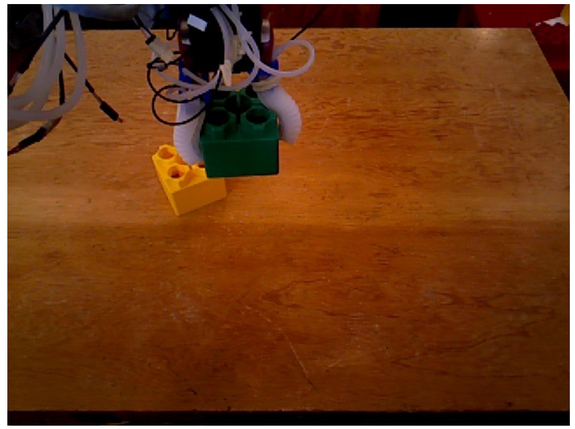
In-hand Object Localization (IOL)

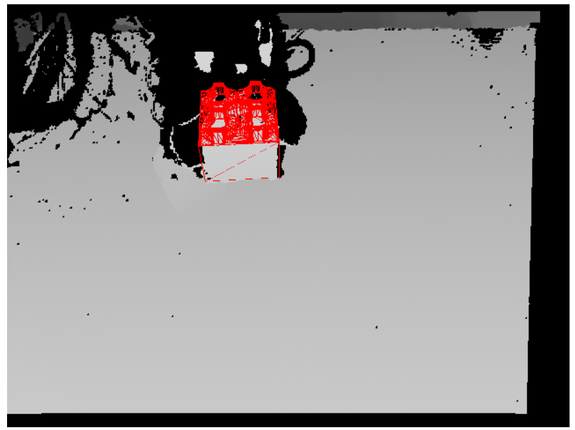
Goal: To estimate the 6-DOF **pose** of the object in the **hand**

Occlusions by fingers!

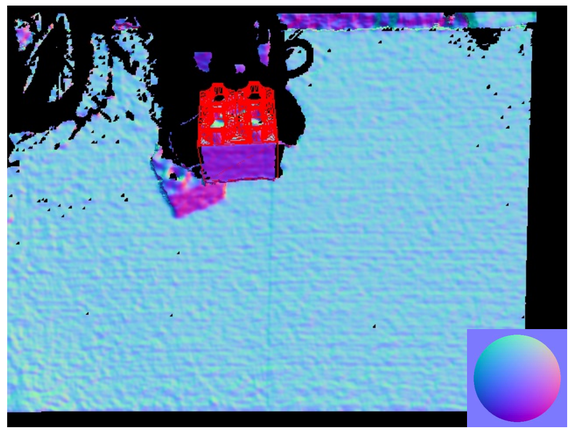


RGB

Hand detection



Depth



Normal

- The hand regions are estimated from a **Gaussian naive Bayes classification** (**H** & **S**).
- The detected finger regions are then *ignored* in the **depth-based object localization**.

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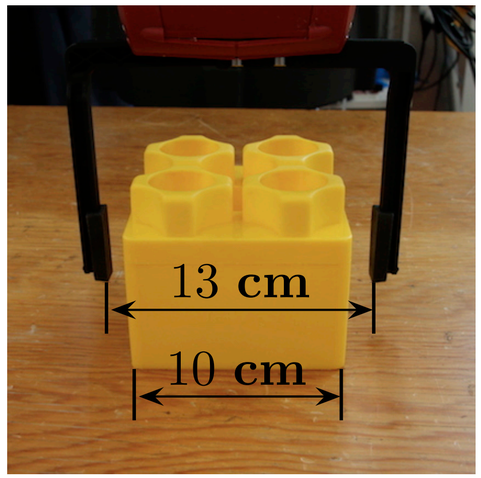
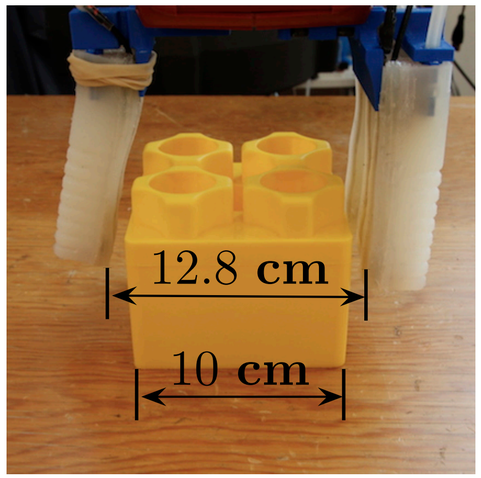
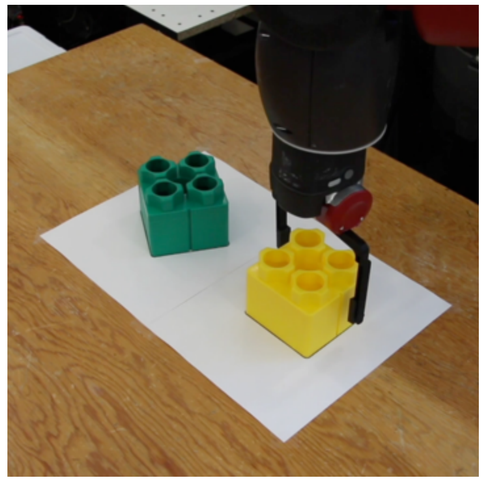
Renderer

Evaluation







- Compare **hard** and **soft** hands
- **With** and **without** the IOL
- 4 configurations: **H**, **HI**, **S**, **SI**
- Fixed the locations of the blocks on the table
- 50 trials with Gaussian noise in object pose estimates

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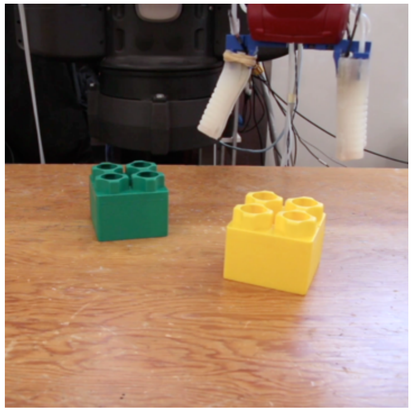
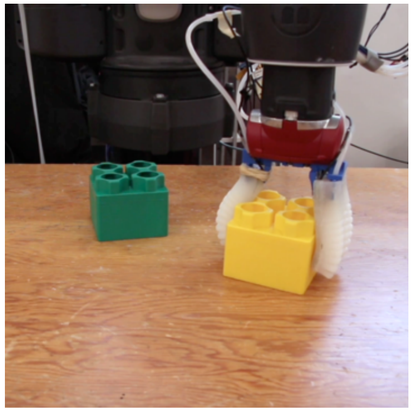
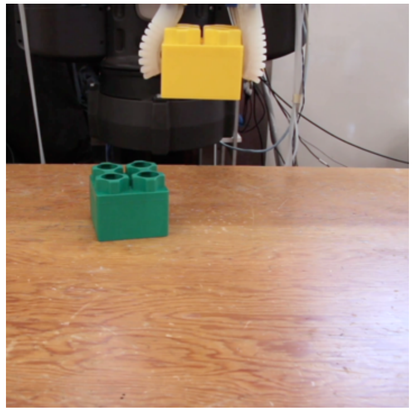
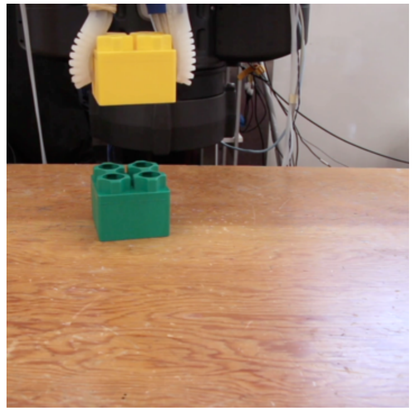
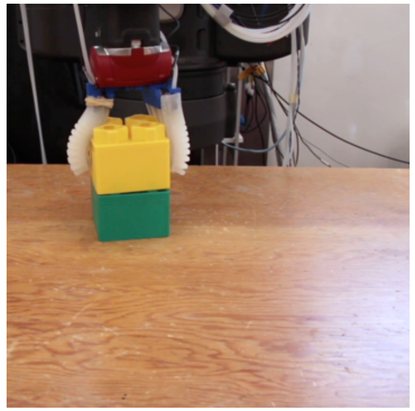
Evaluation


pre-grasping


post-grasping


IOL


approaching


insertion


lifting

- if two blocks are lifted together, *success*
- otherwise, *failure*

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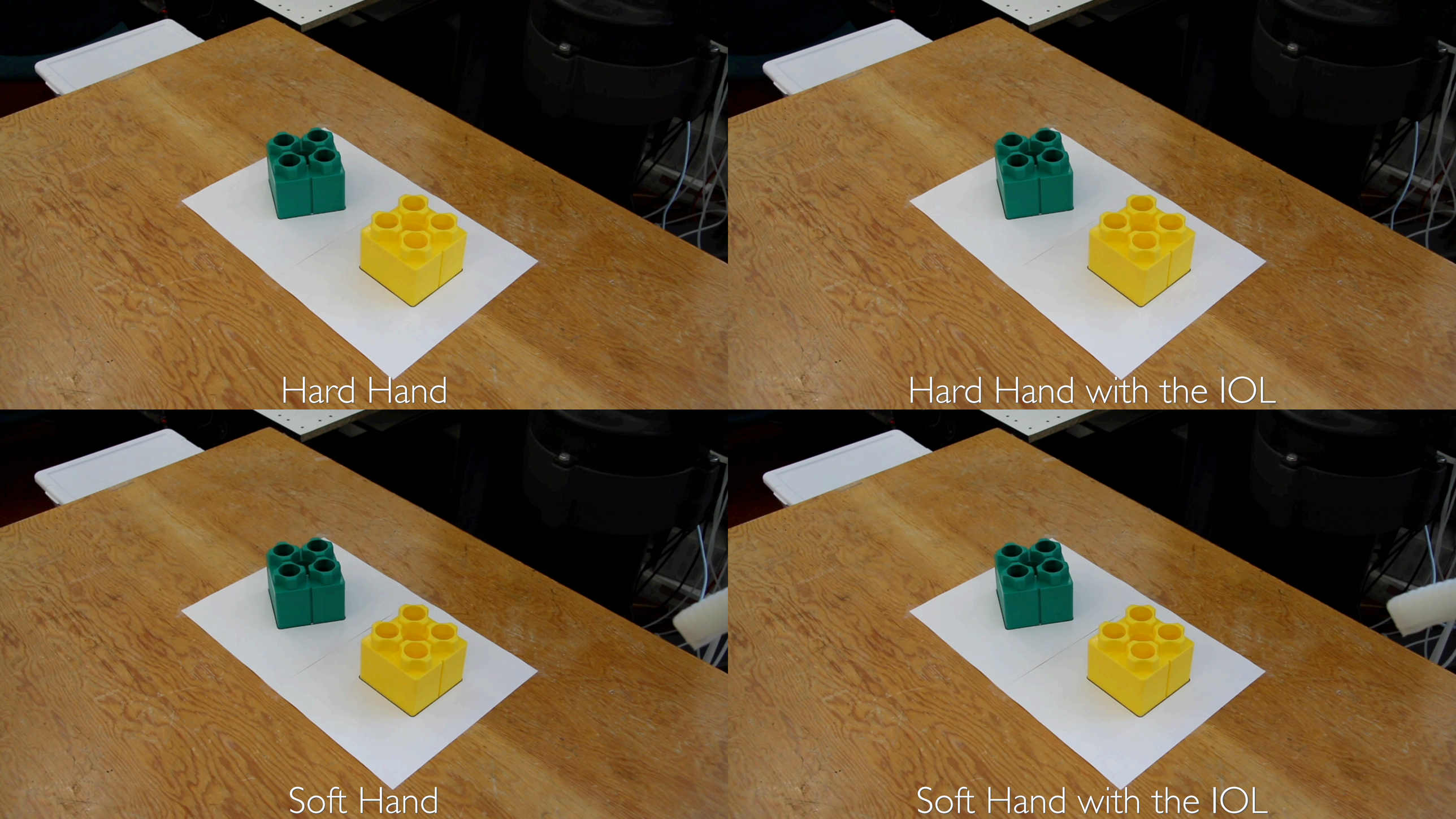
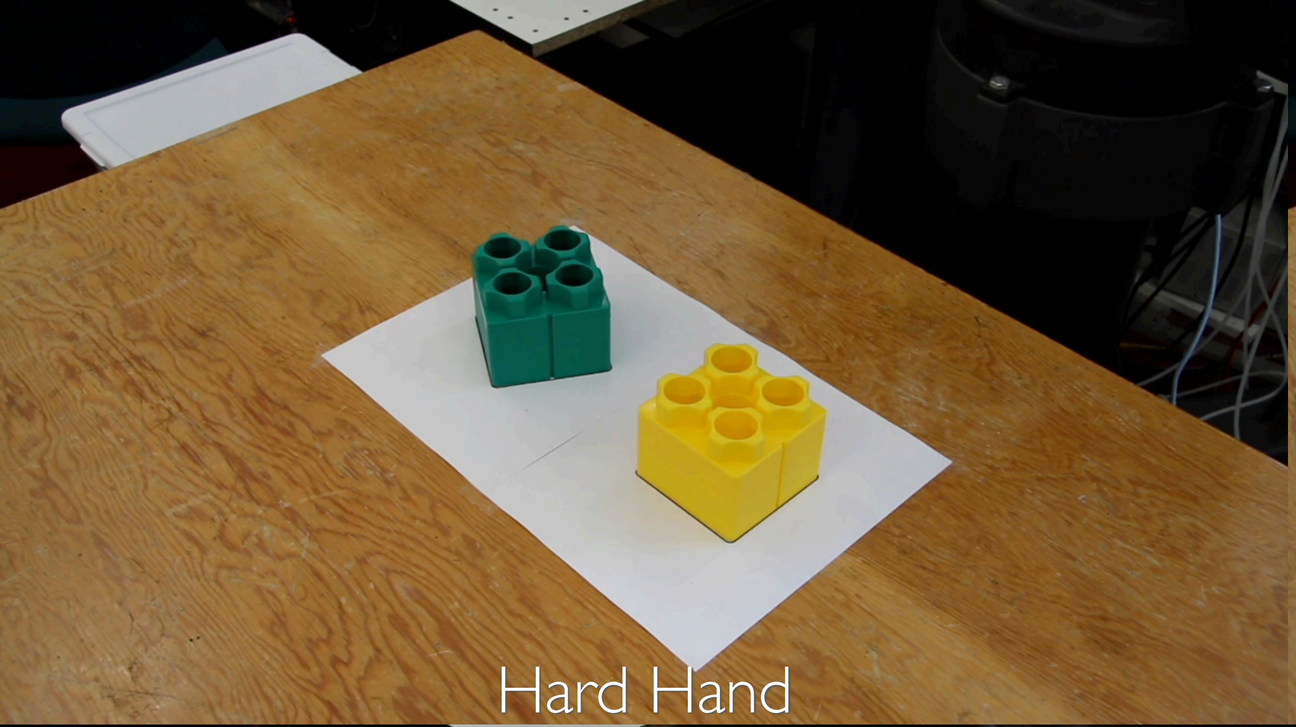
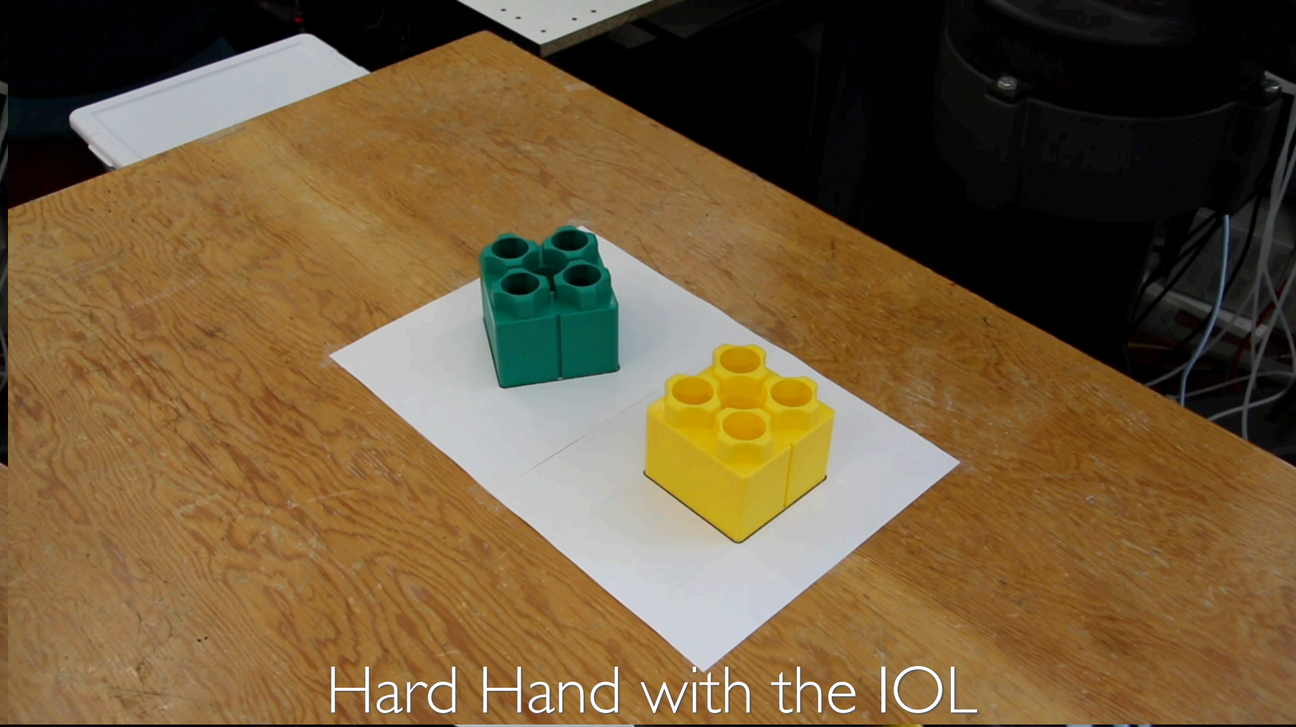
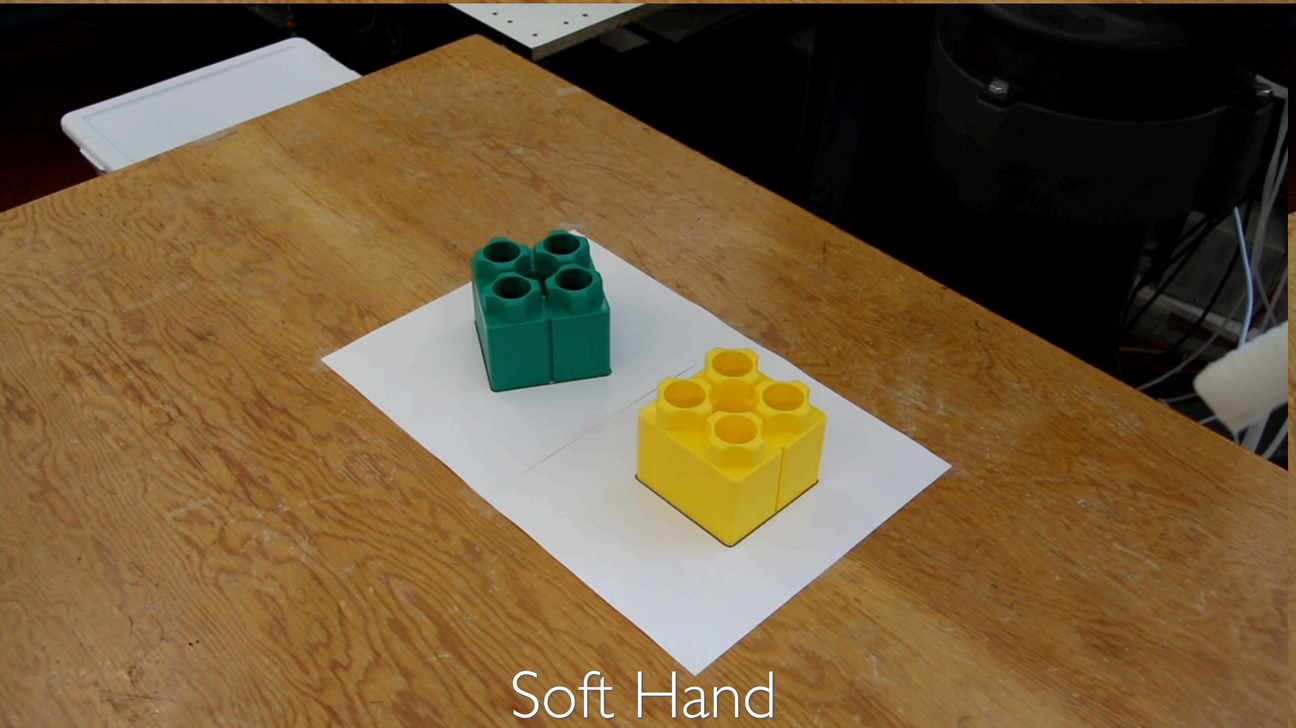
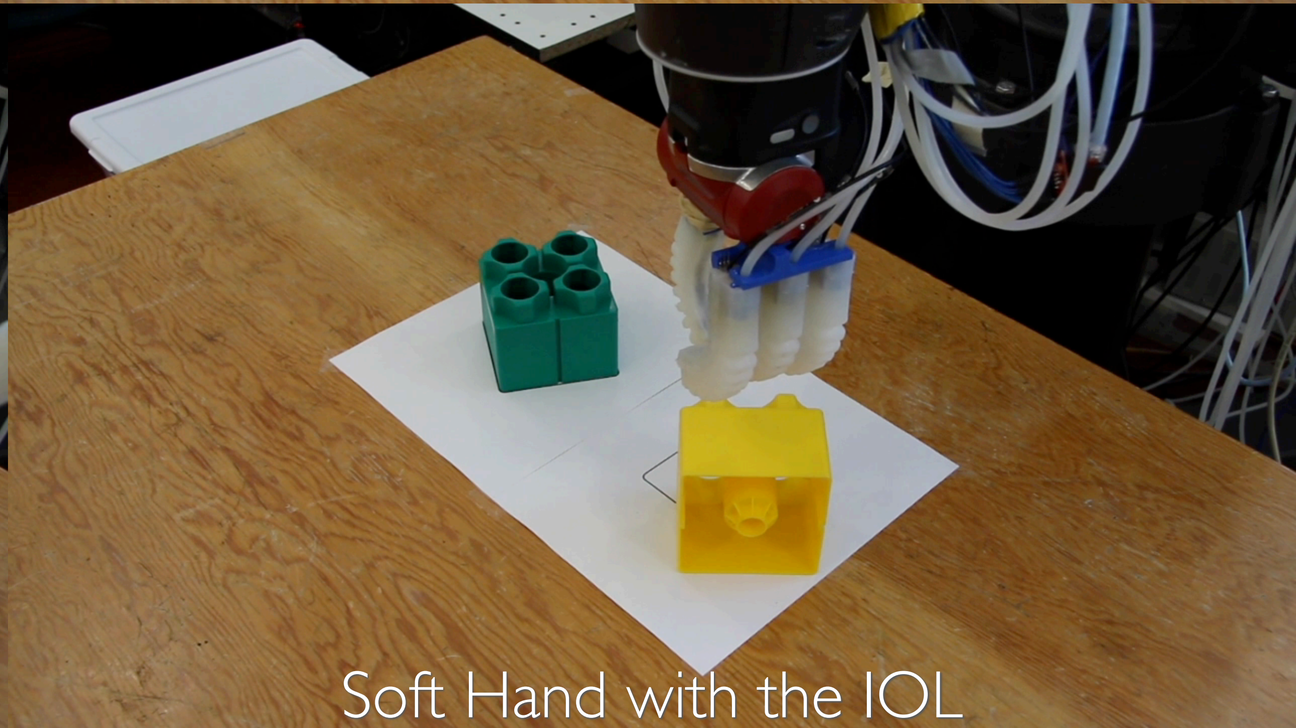

Hard Hand
Hard Hand with the IOL
Soft Hand
Soft Hand with the IOL

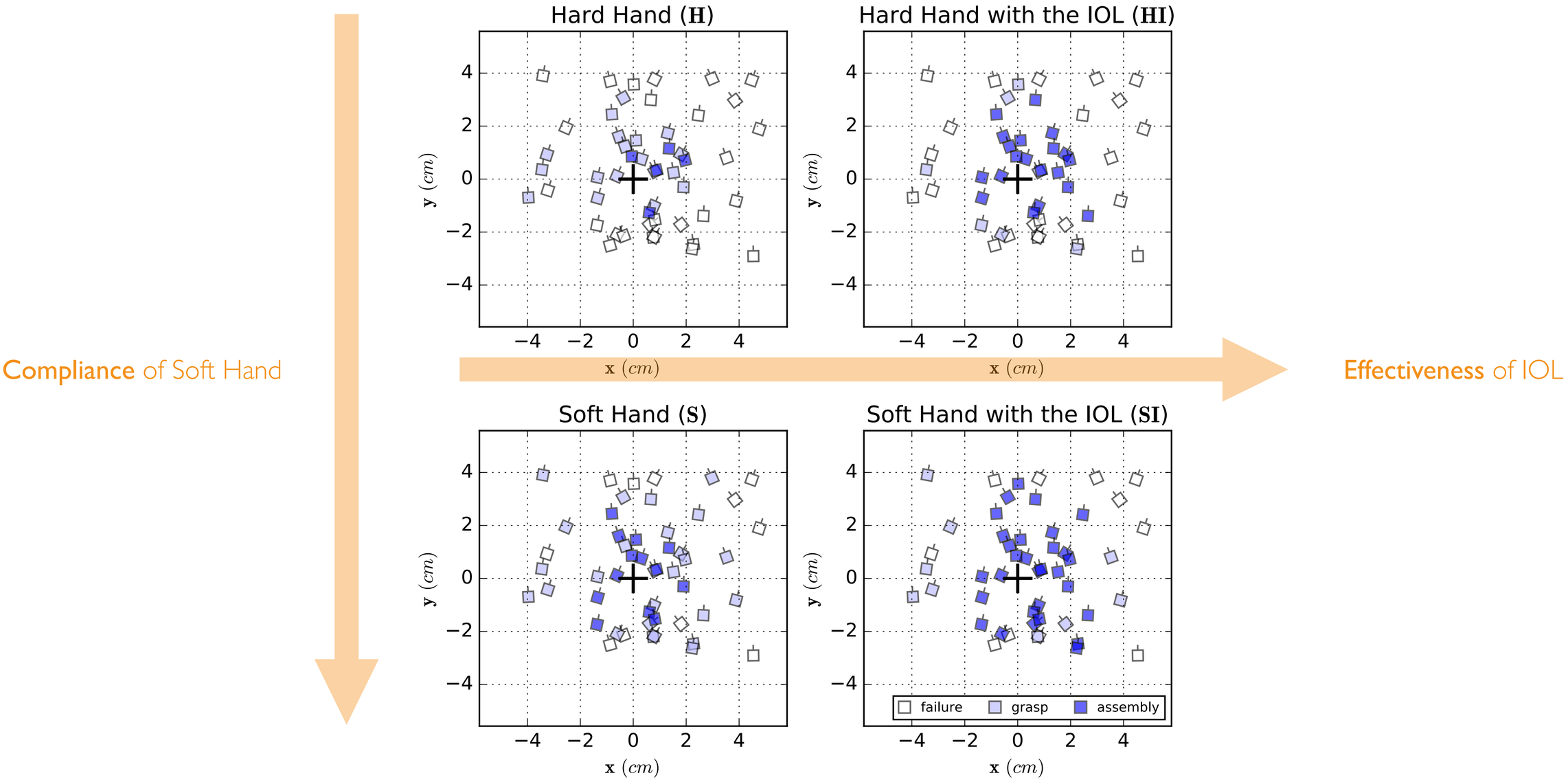

Hard Hand


Hard Hand with the IOL


Soft Hand


Soft Hand with the IOL

Evaluation: Fixed + Noise



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Evaluation: Fixed + Noise

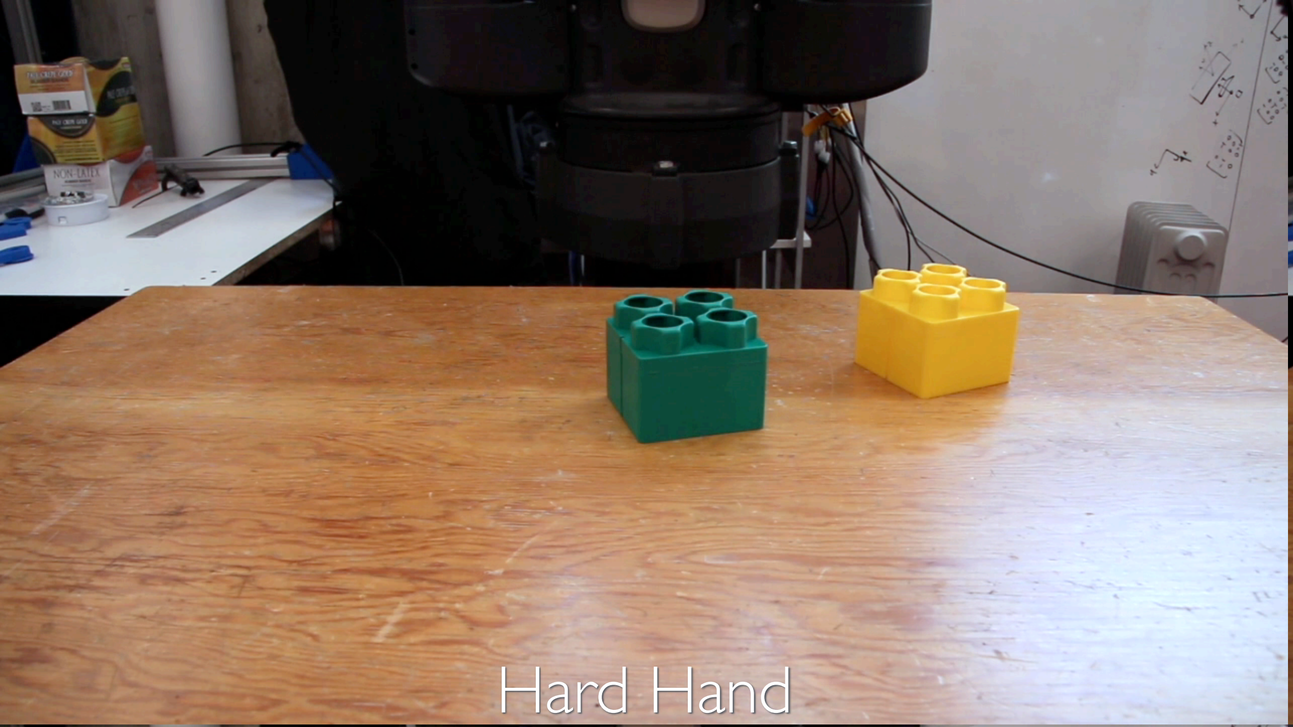
Table 1: Success rates for 50 trials of the Gaussian noise experiment.

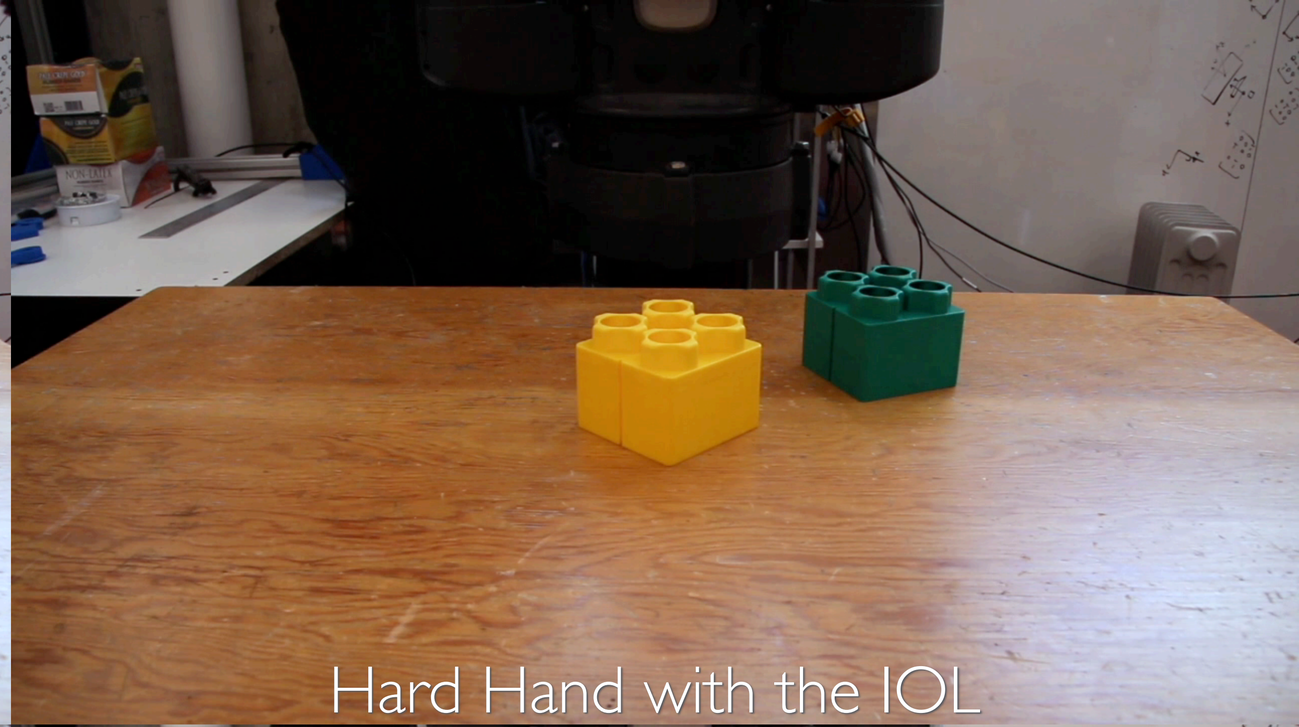
Measure	Hard Hand		Soft Hand	
	¬IOL (**H**)	IOL (**HI**)	¬IOL (**S**)	IOL (**SI**)
# of Failure	27	23	11	11
# of Grasping	18	7	26	9
# of Assembly	5	20	13	30
Successful Grasping†	46%	54%	78%	78%
Successful Assembly†	10%	40%	26%	60%

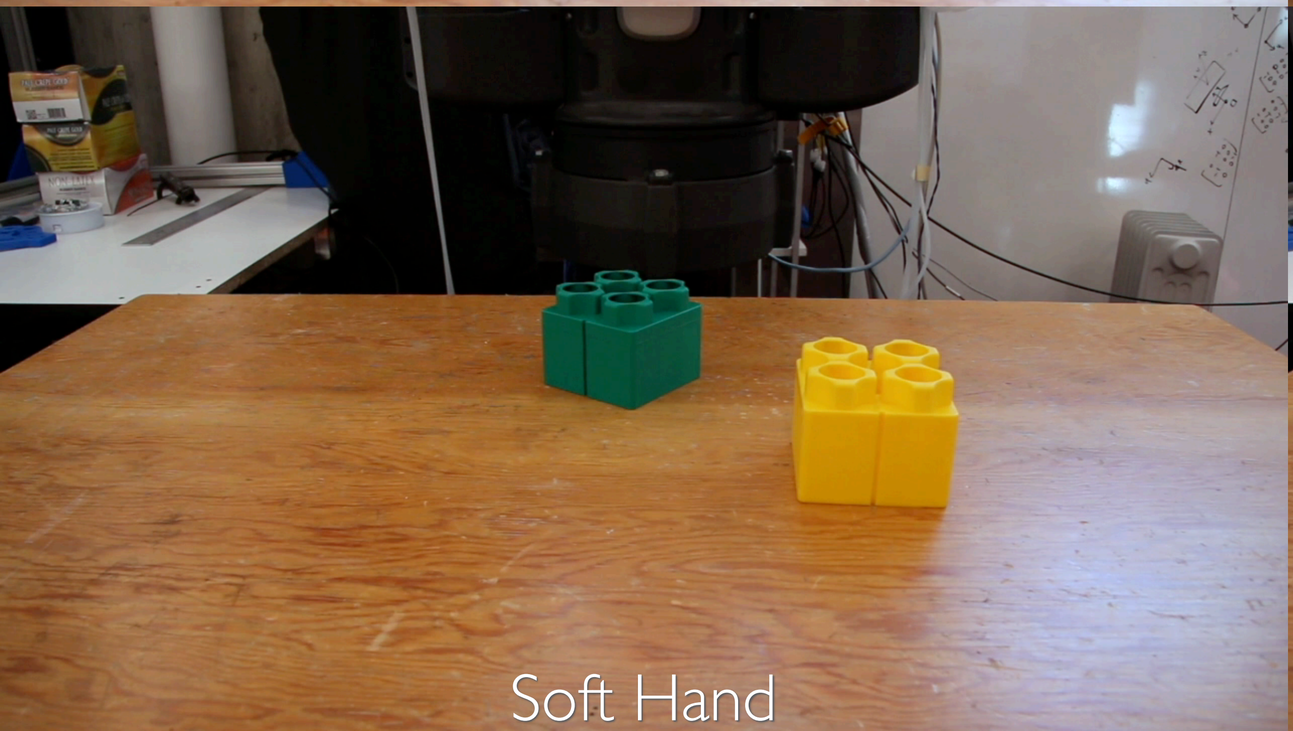
† The success rate of grasping considers both '# of grasping' and '# of assembly'.

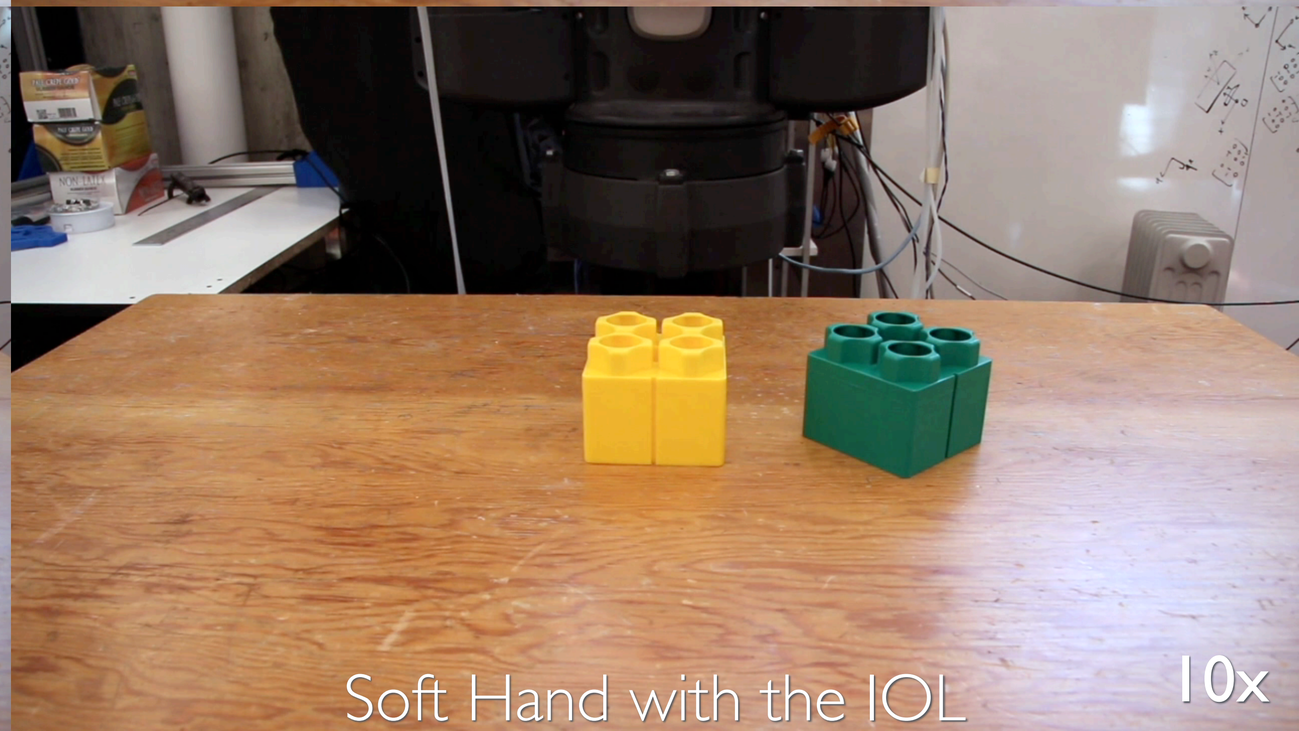
Compliance of Soft Hand

Effectiveness of IOL


Hard Hand


Hard Hand with the IOL

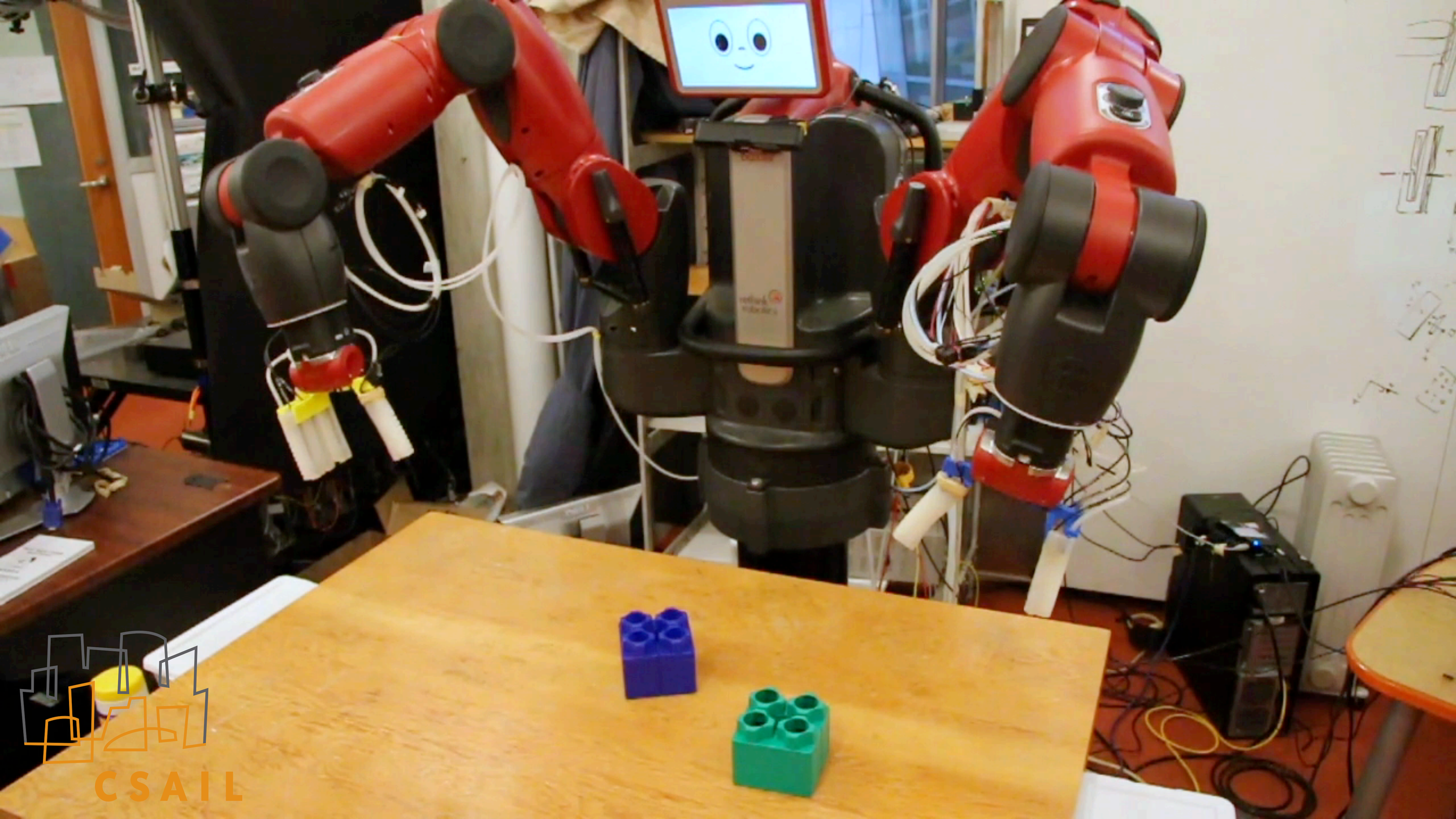

Soft Hand


Soft Hand with the IOL
10x

Evaluation: Random locations

Table 2: Success rates for 100 trials of the complete system experiment.

Measure	Hard Hand		Soft Hand	
	¬IOL (**H**)	IOL (**HI**)	¬IOL (**S**)	IOL (**SI**)
Successful Assembly	41%	66%	72%	92%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Conclusions

- **Soft hands** + an RGB-D **object localization**
- **Grasping** known objects and **connecting** two objects
- Soft hands are more **robust** than hard hands w.r.t. uncertainty.
- **In-hand object localization** (**IOL**) enables soft hands to perform an **assembly** task **reliably**.

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The support is gratefully acknowledged.