Robotic Grasping for Daily-Living Manipulation Tasks

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Robot Perception and Action Lab

Grasp for Manipulation

- Manipulating an instrument
  - Task wrench: interactive force and torque between the instrument and environment
  - Instrument motion

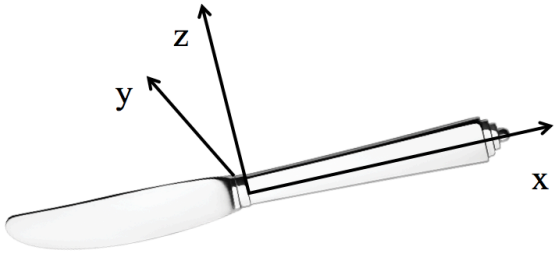
Task-Based Grasp Quality Measures

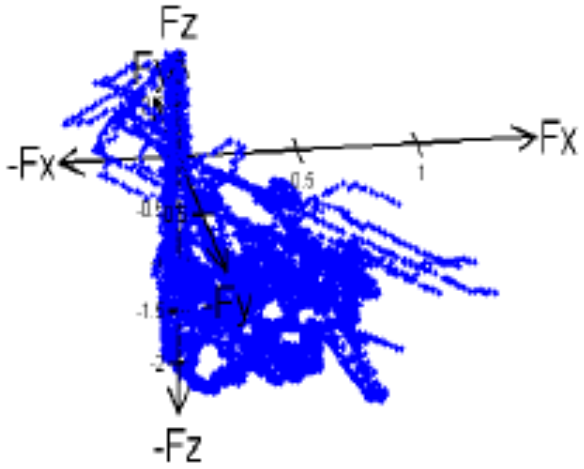
- Efficiently transfer arm motion to instrument motion
- Provide required force and torque

Use a Knife

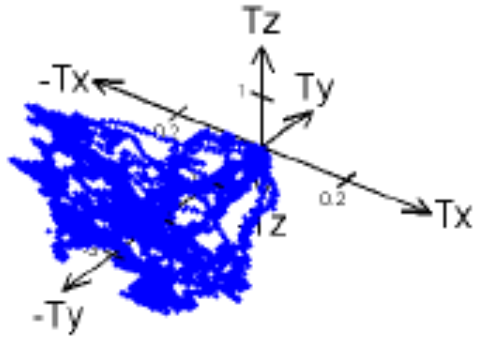
Use a Knife

Task 1: cutting





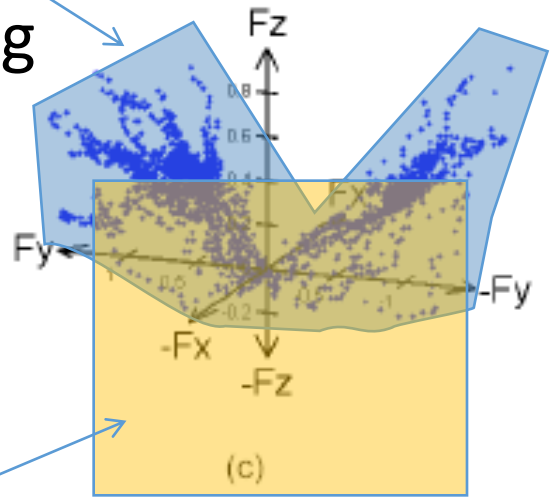
(a)



(b)

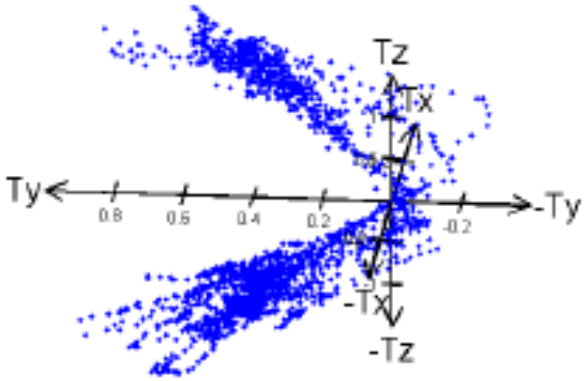
Task Coverage

Task 2: butter spreading



(c)

Force closure



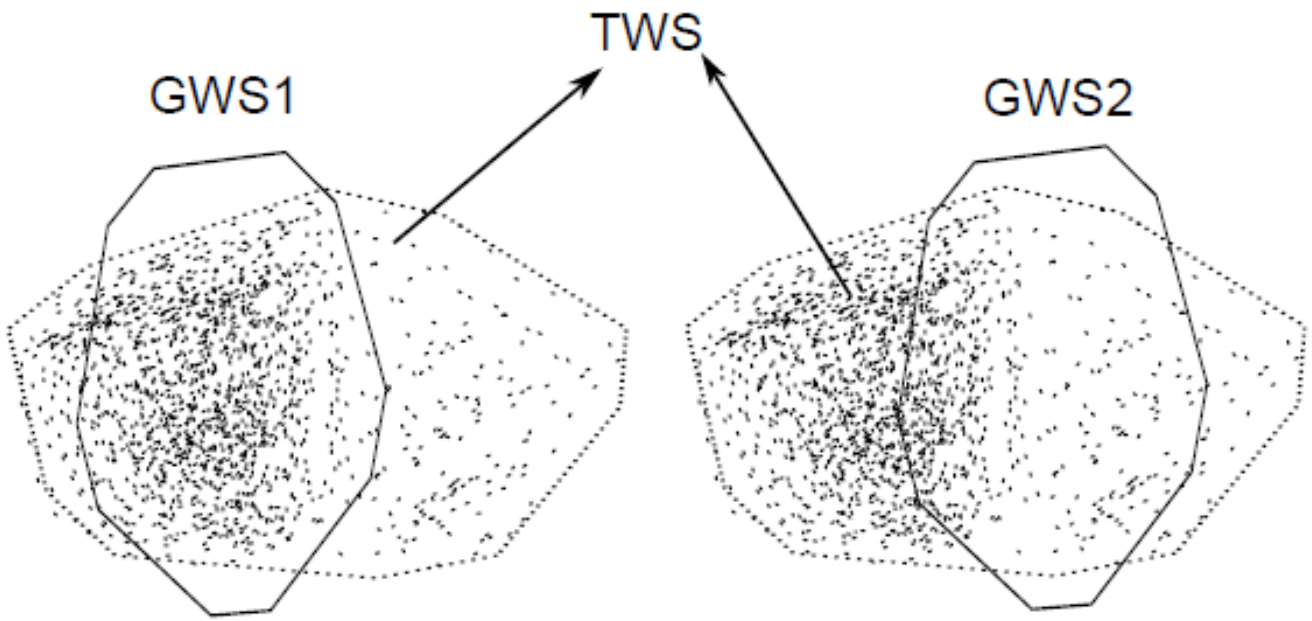
(d)

Task-Oriented Grasping

- Z. Li and S. S. Sastry. Task-oriented optimal grasping by multifingered robot hands. *IEEE Journal of Robotics and Automation*, 4(1):32–44, feb 1988.
- Nancy Pollard
- Jeff Trinkle, Zexiang Li
- Gerd Hirzinger
- Danica Kragic
- Many others
- Approximate the task wrench space with geometry shapes

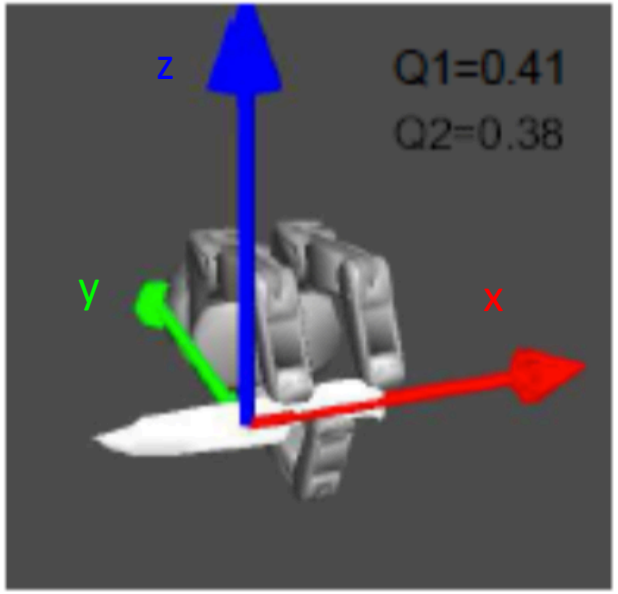
Quality Measure: Task Wrench Coverage

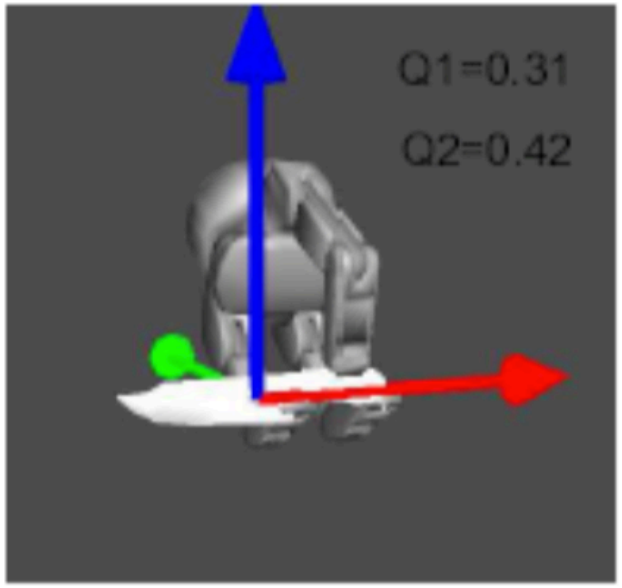
$$Q_w = \frac{Count\{\mathrm{O}|O \in \mathrm{GWS} \cap \mathrm{TWS}\}}{Count\{\mathrm{O}|O \in \mathrm{TWS}\}}$$

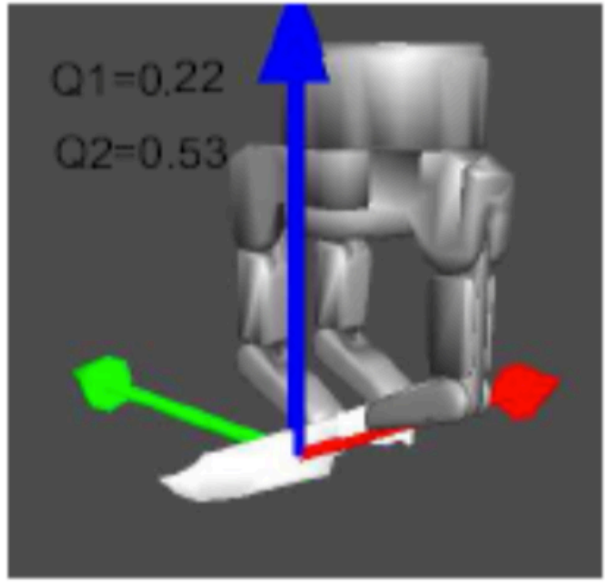


Task 1

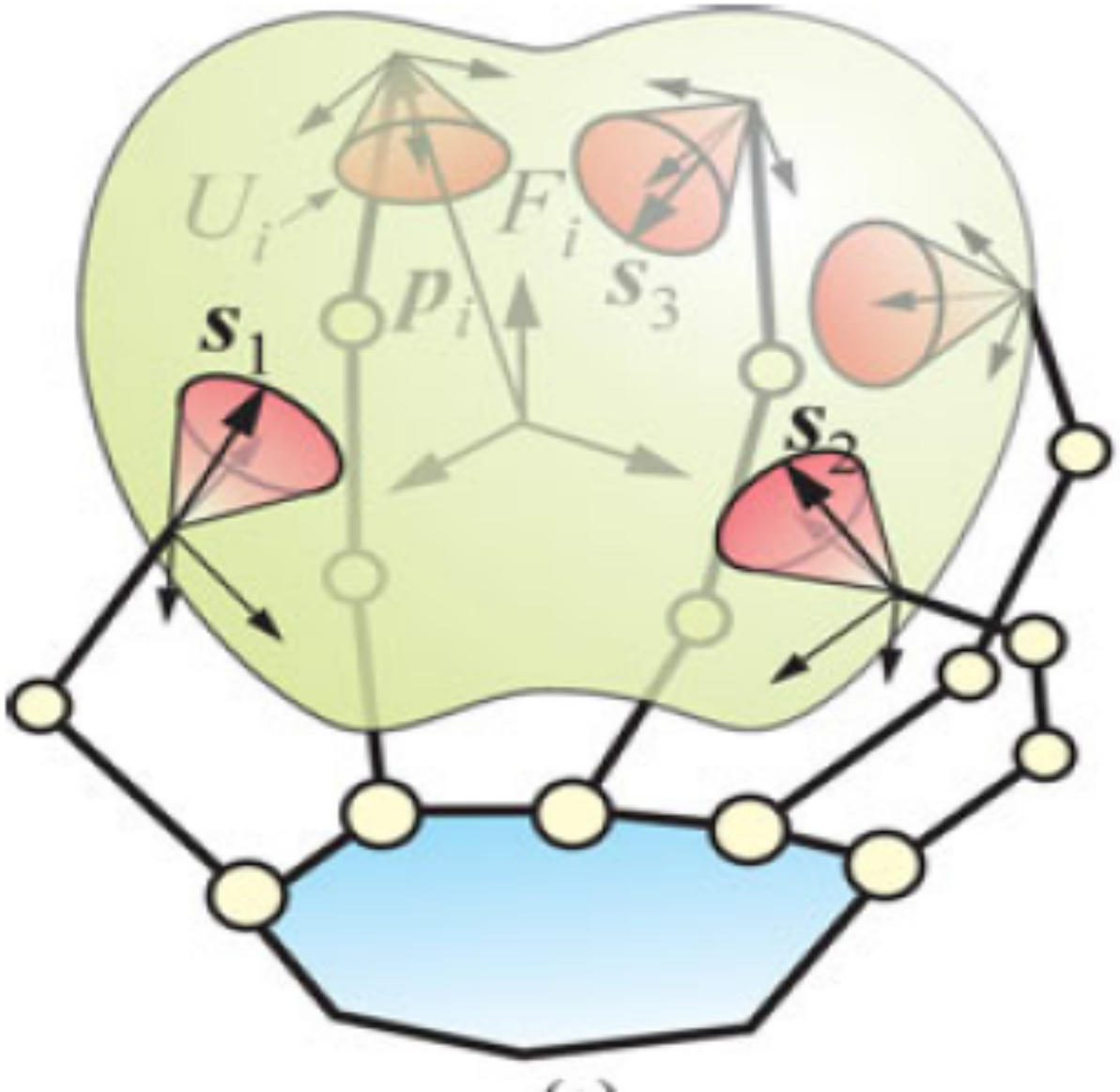
Task 2





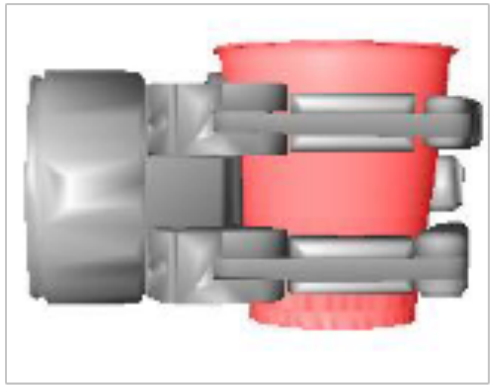


Grasp Definition

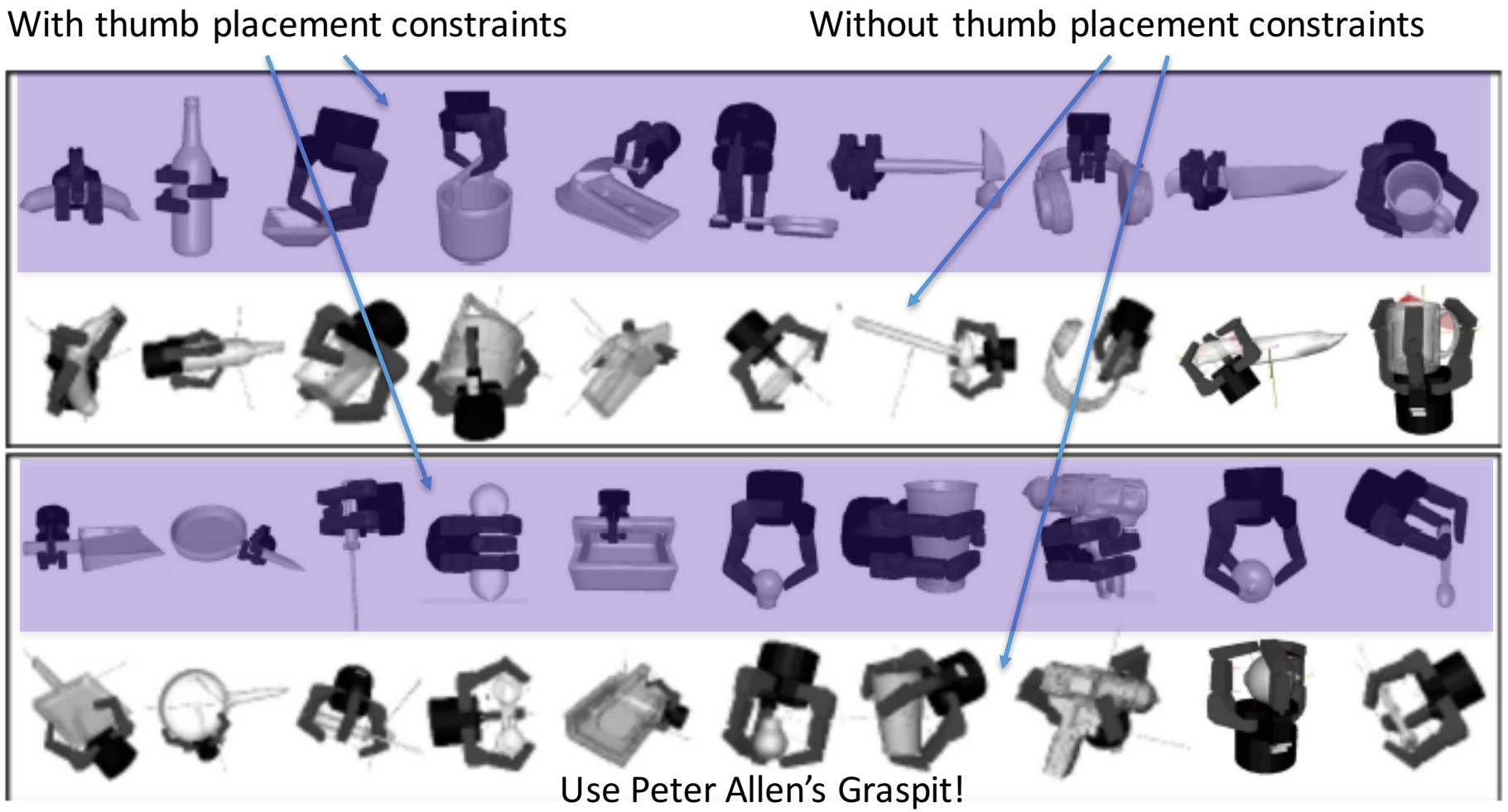


Learn thumb placement to reduce search space

Thumb Placement

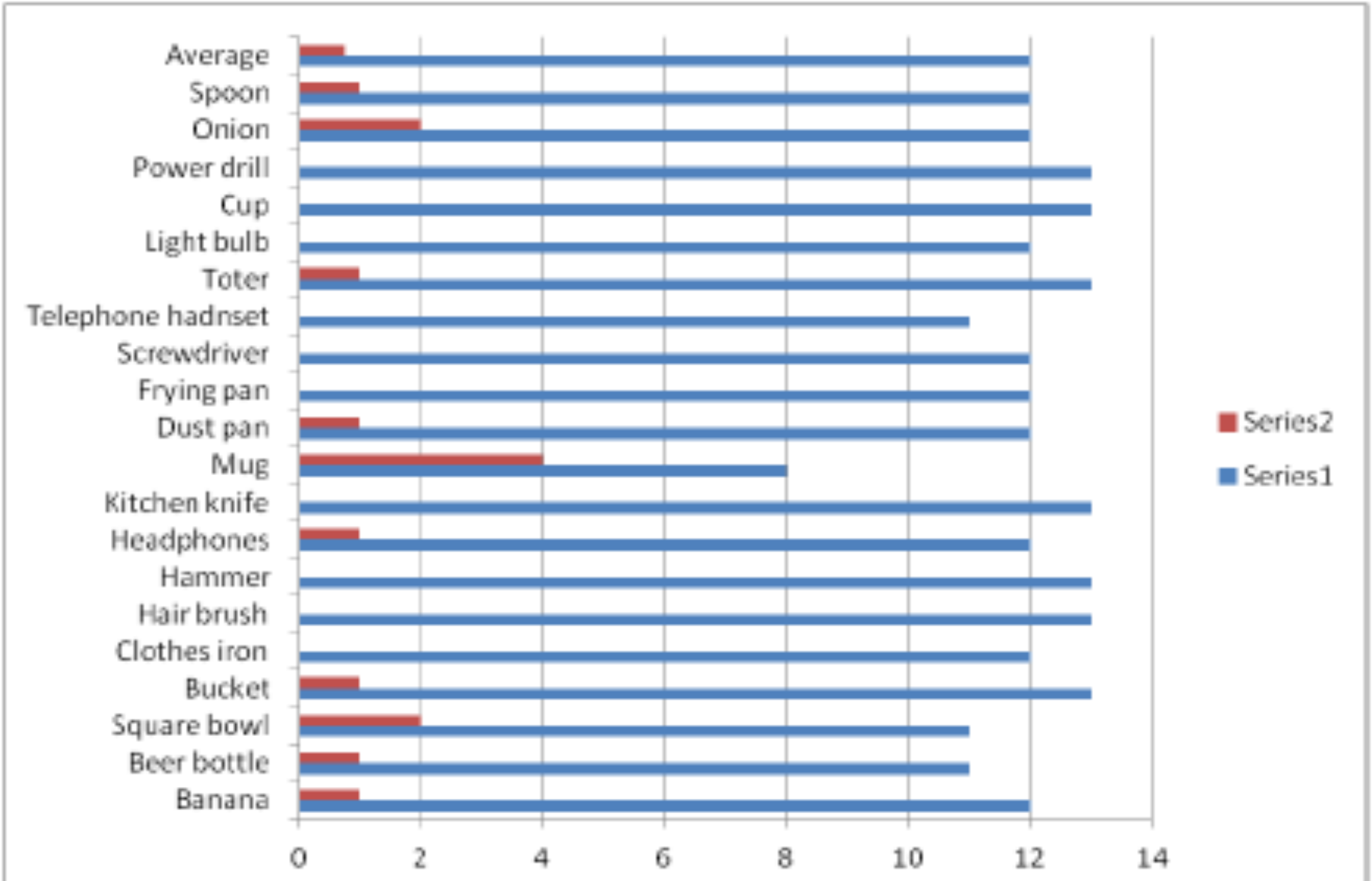


Evaluation Using Barrett Hand



Use Peter Allen's Graspit!

Lin, and Sun (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.


Average
Spoon
Onion
Power drill
Cup
Light bulb
Toter
Telephone hadnset
Screwdriver
Frying pan
Dust pan
Mug
Kitchen knife
Headphones
Hammer
Hair brush
Clothes iron
Bucket
Square bowl
Beer bottle
Banana
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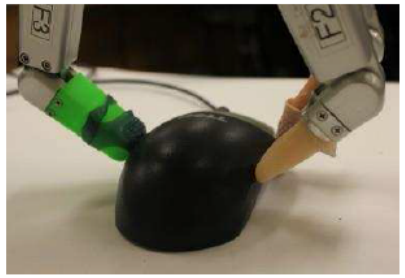
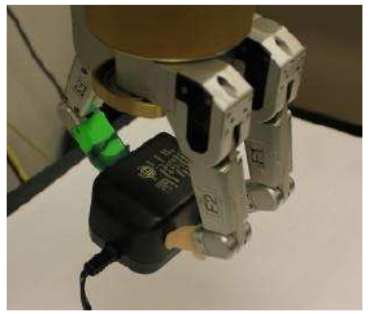
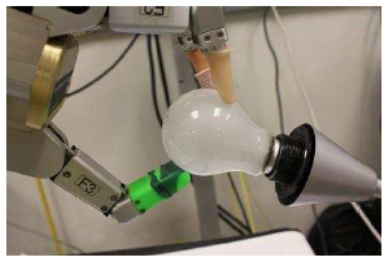
10
12
14
Series2
Series1

Success Rate of Real Execution

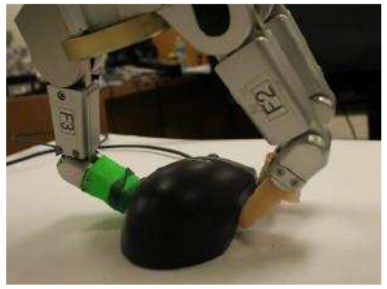
Our approach

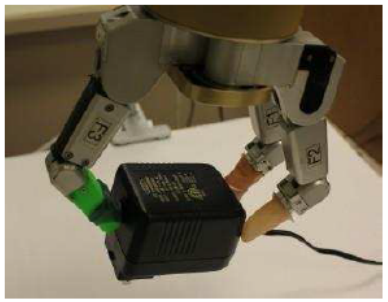


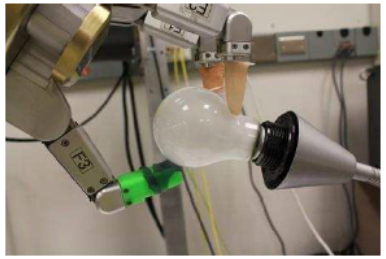




Force-closure approach





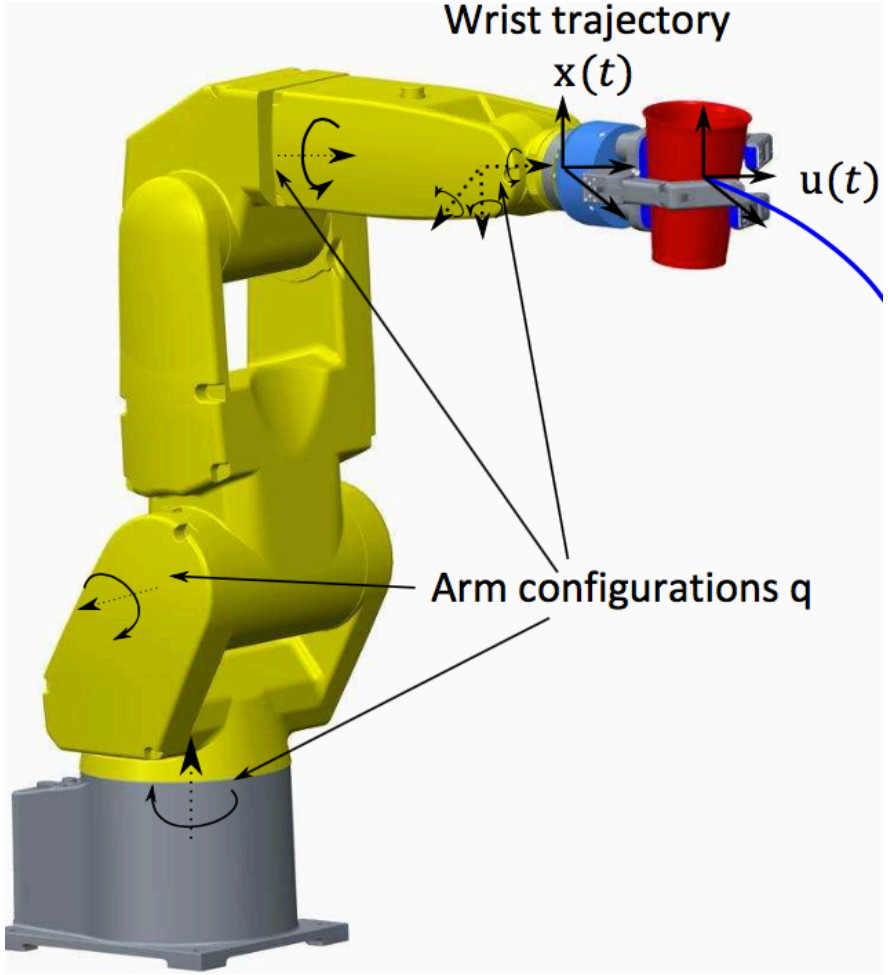


Task	Success Rate of Task Disturbance Based Grasp Planning	Success Rate of non-task oriented Grasp Planning
Task 1	60%	40%
Task 2	80%	70%
Task 3	70%	20%
Overall	70%	43.3%

Lin and Sun, Grasp Planning to Maximize Task Coverage, Intl. Journal of Robotics Research, vol. 34 no. 9 1195-1210, 2015


A haptic device is used to
demonstrate a task.

Grasp Measure Based-on Manipulator Efficiency in Task



Instrument trajectory vs. Wrist trajectory

When instrument trajectory is fixed, different grasps will need different wrist trajectories.

Different wrist trajectories needs completely different arm motions.

Grasp => arm motion

Best Grasp Requests Less Arm Motion

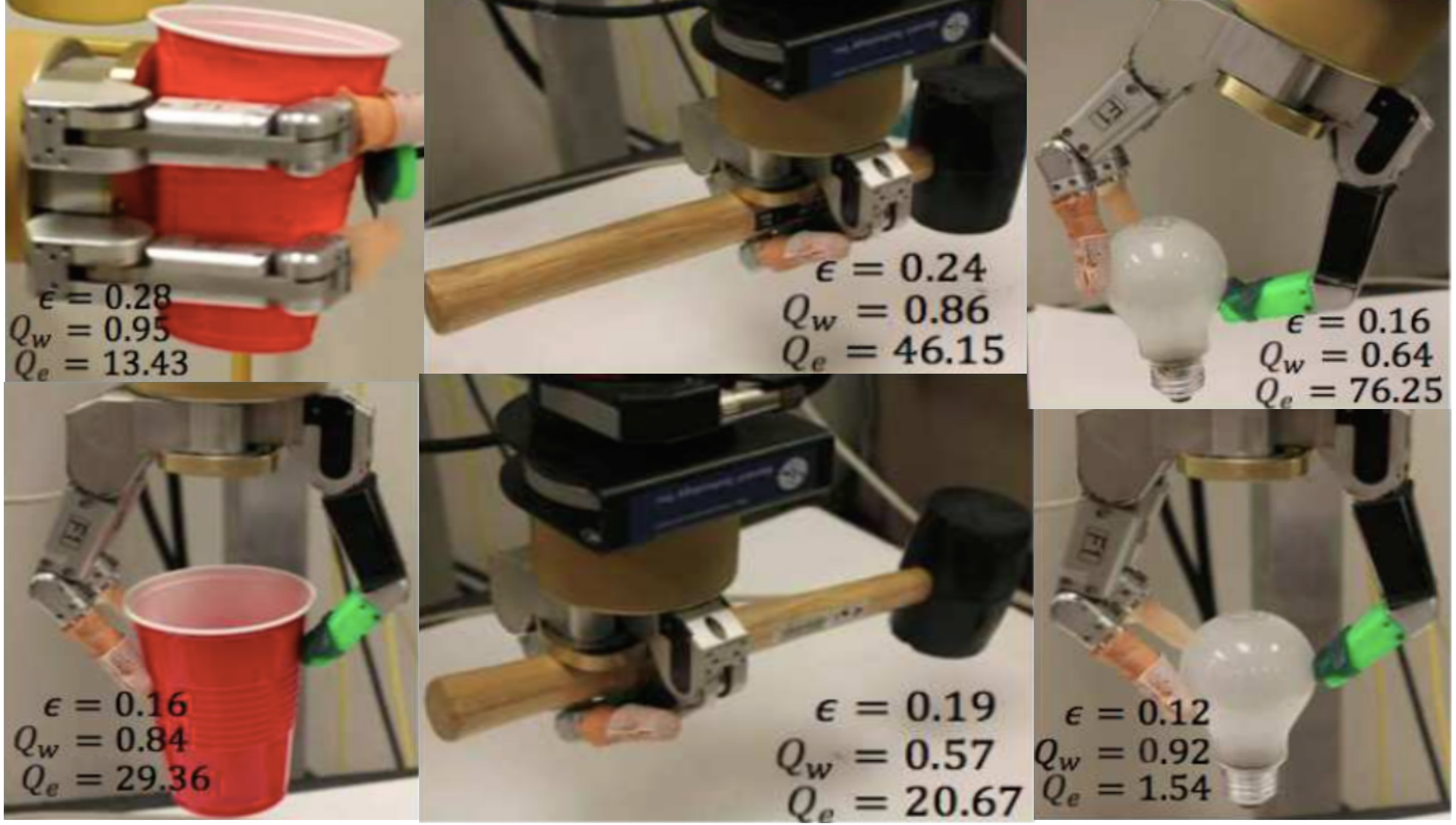
M-joint vector of torques from the actuator

$$\tau = M(\mathbf{q})\ddot{\mathbf{q}} + C(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}} + F(\dot{\mathbf{q}}) + G(\mathbf{q}) + J(\mathbf{q})\mathbf{f}$$

Manipulator's motion effort over time

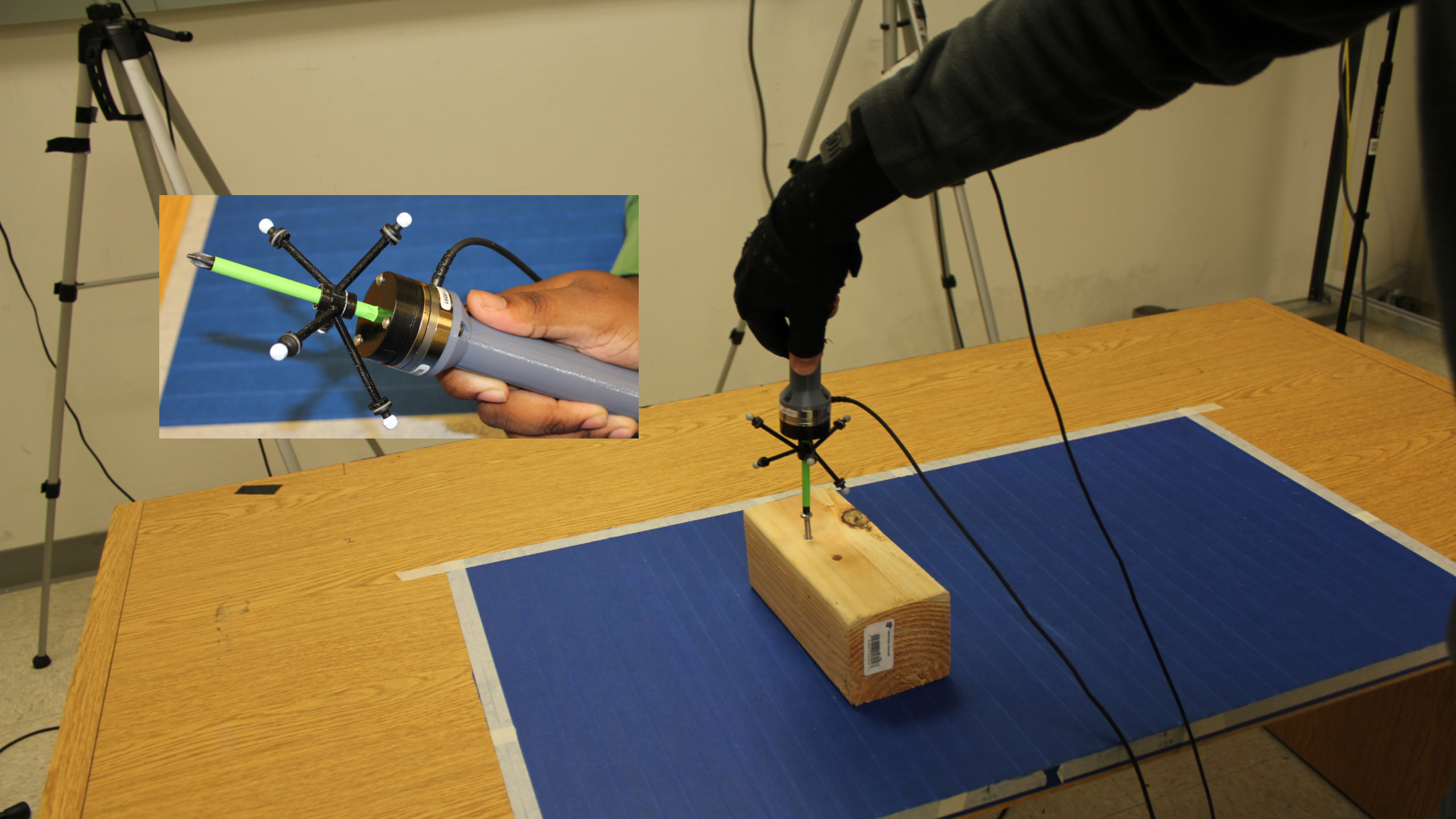
$$Q_e = \int_{t_0}^{t_n} \tau(t)^T \tau(t) dt$$

An example of task demonstration. Motion and disturbance distribution are captured.



Lin, Y. and Sun, Y. (2015) Task-Based Grasp Quality Measures for Grasp Synthesis, IROS, 485-490.

Physical Interaction Data Collection

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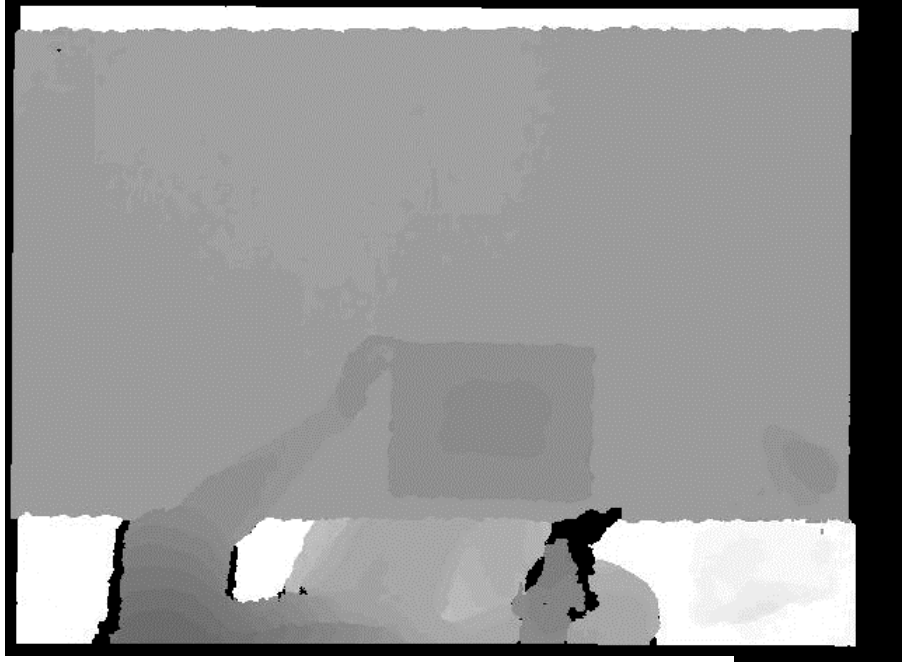
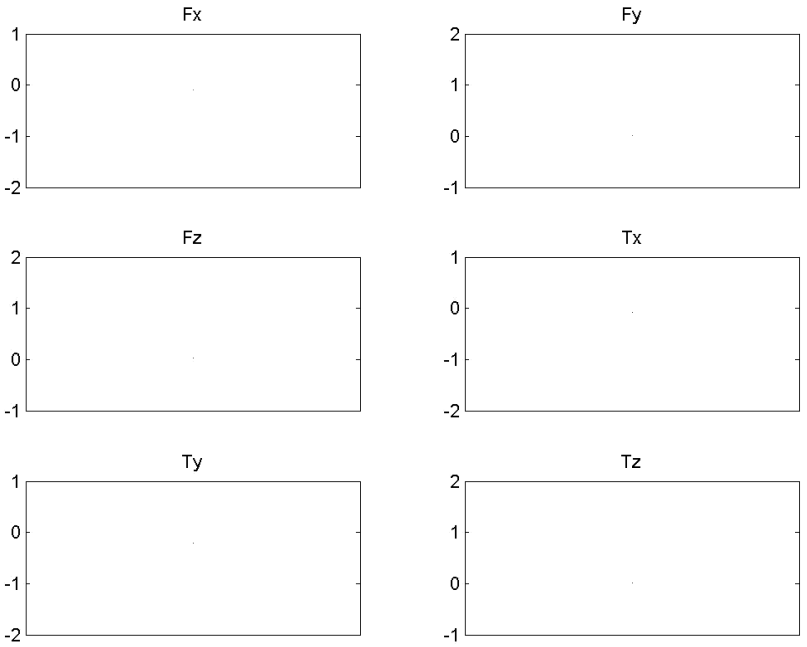
STANLEY

Instrumental ADLs

- Food preparation
- Basic house maintenance
- Basic housework
- Personal hygiene
- Total: 36 manipulation tasks, around 2000 motion trajectories

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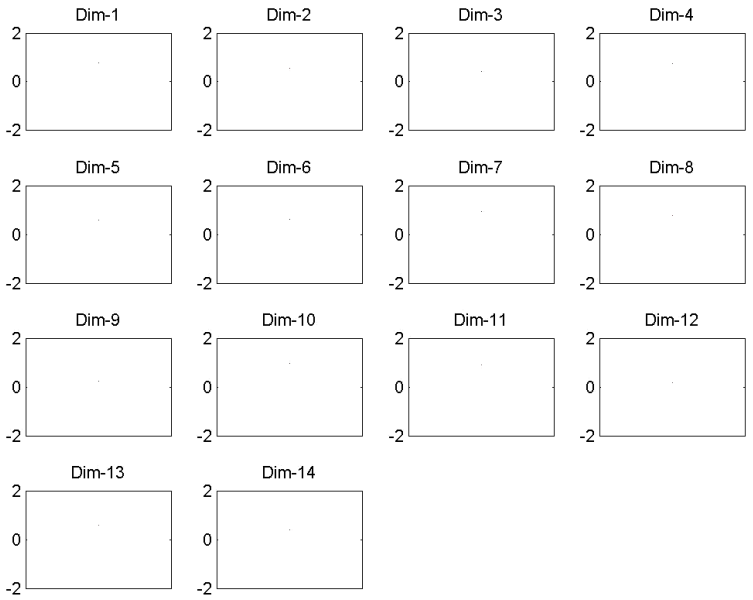
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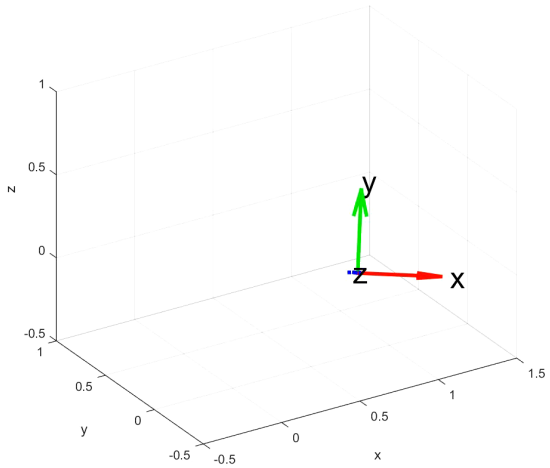
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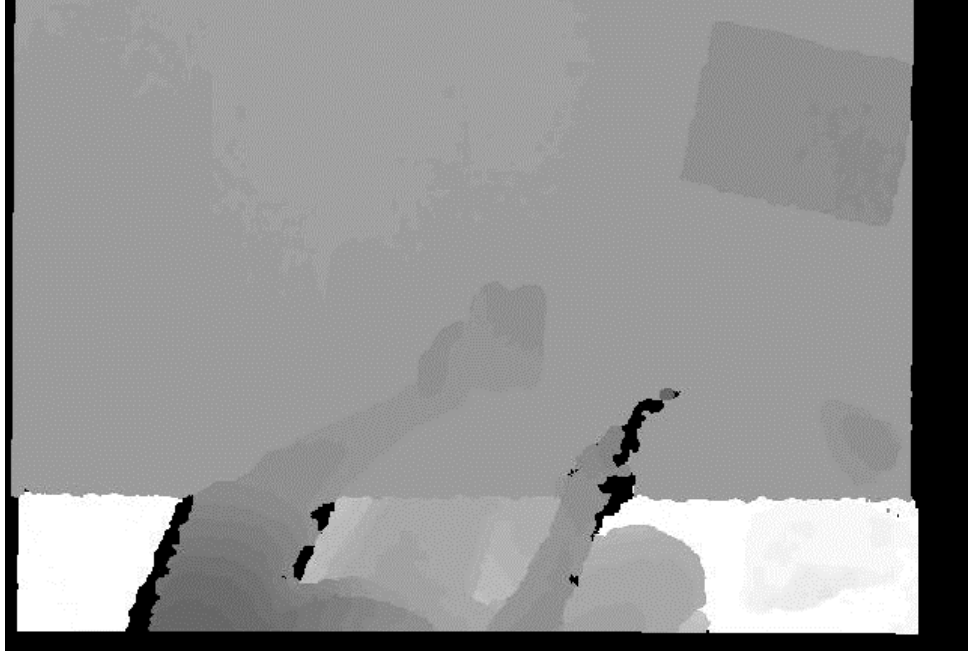

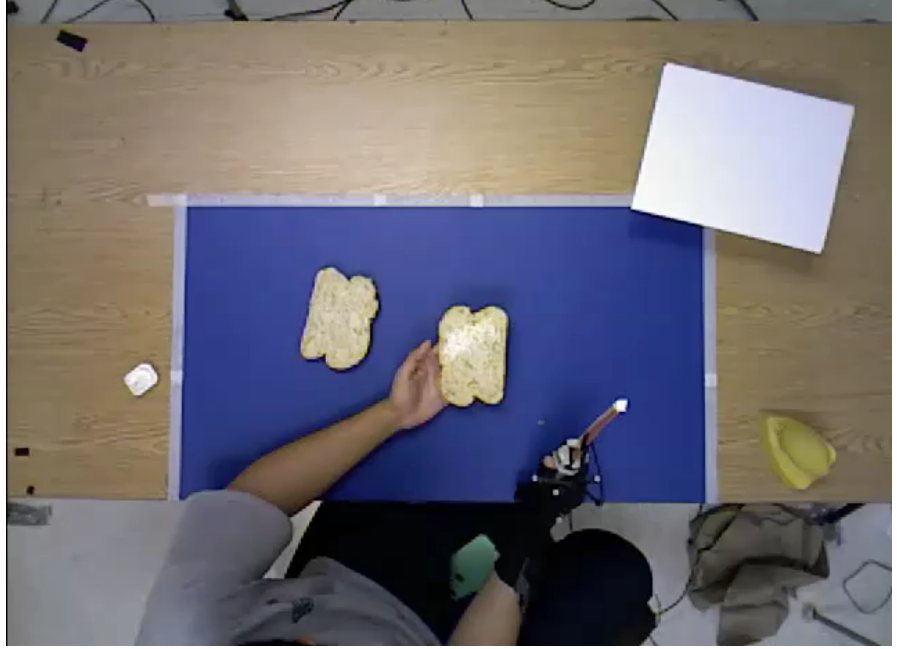

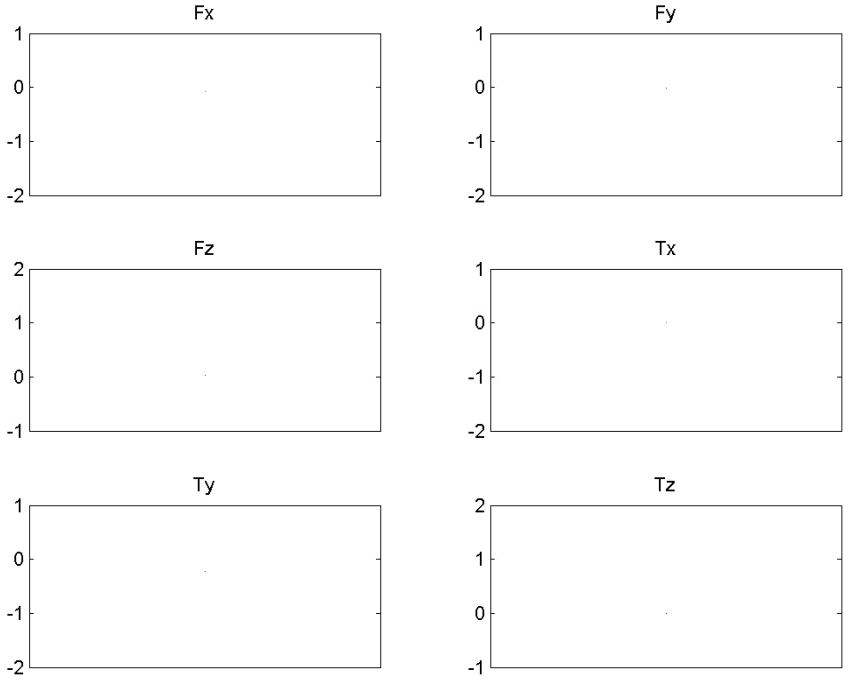
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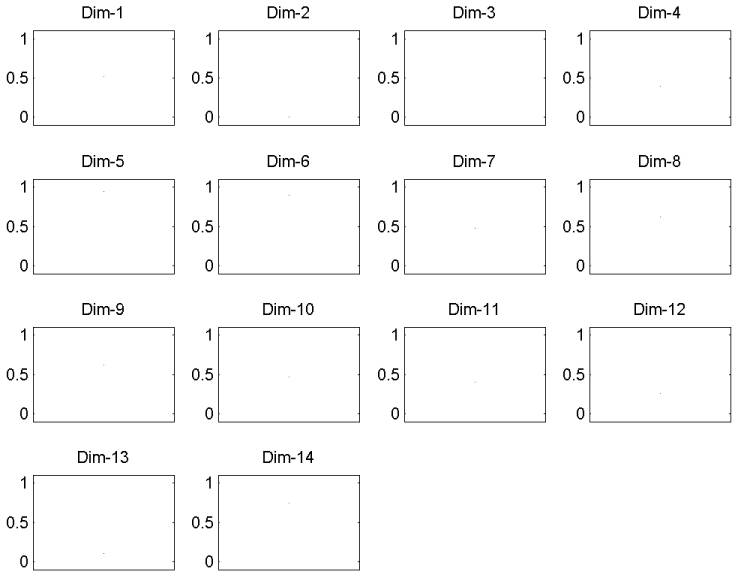
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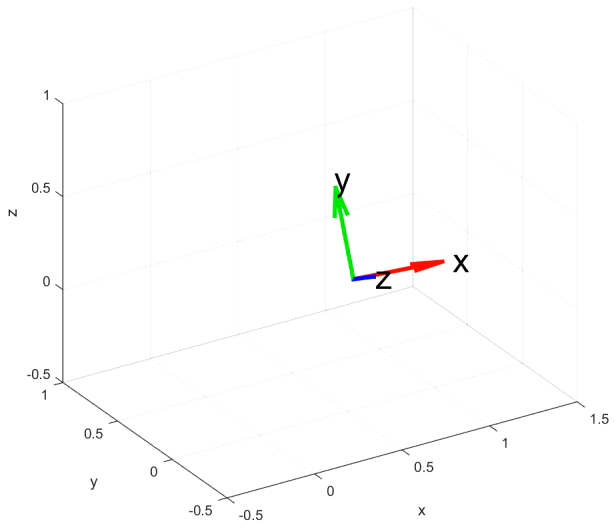
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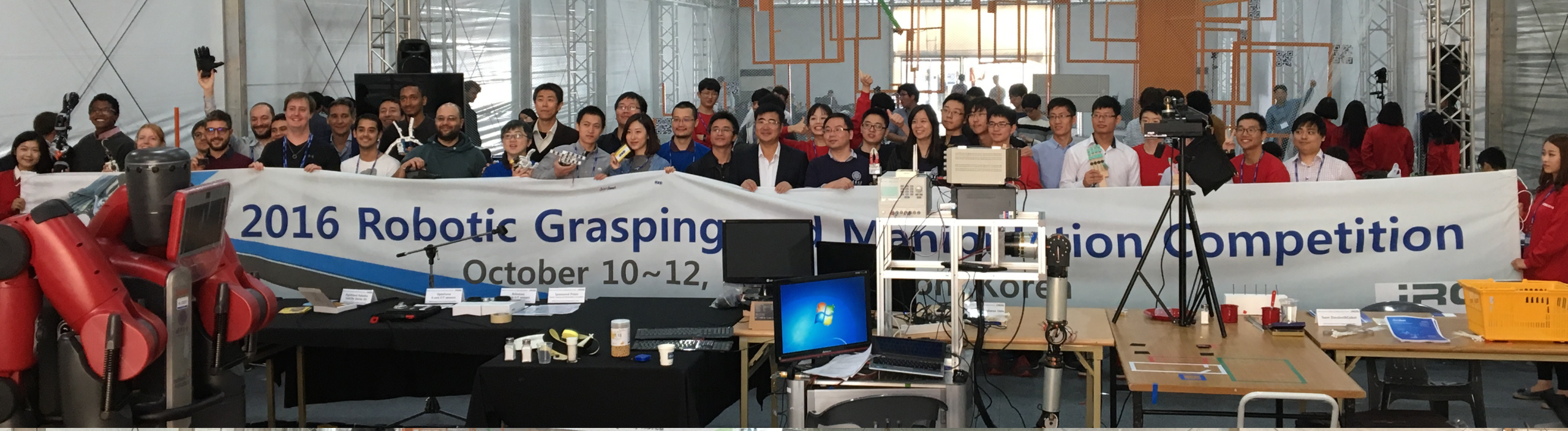
Support

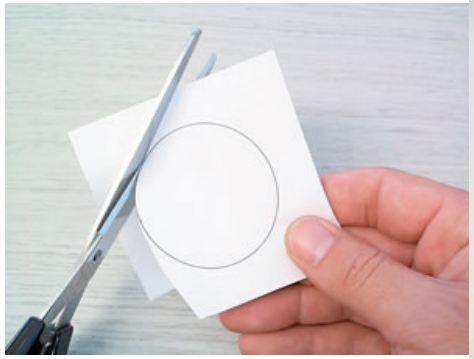
This material is based upon work supported by the National Science Foundation under Grants No. 1421418 and No. 1560761.


2016 Robotic Grasping
October 10~12,

- Use a spoon to pick up peas
- Hang towel on rack
- Use a spoon to stir water in a cup
- Shake salt shaker
- Plug into a socket
- Hammer a nail
- Transfer straw into a to-go cup with lid
- Putting on or removing bolts from nuts with a nut driver
- Extend and press syringe

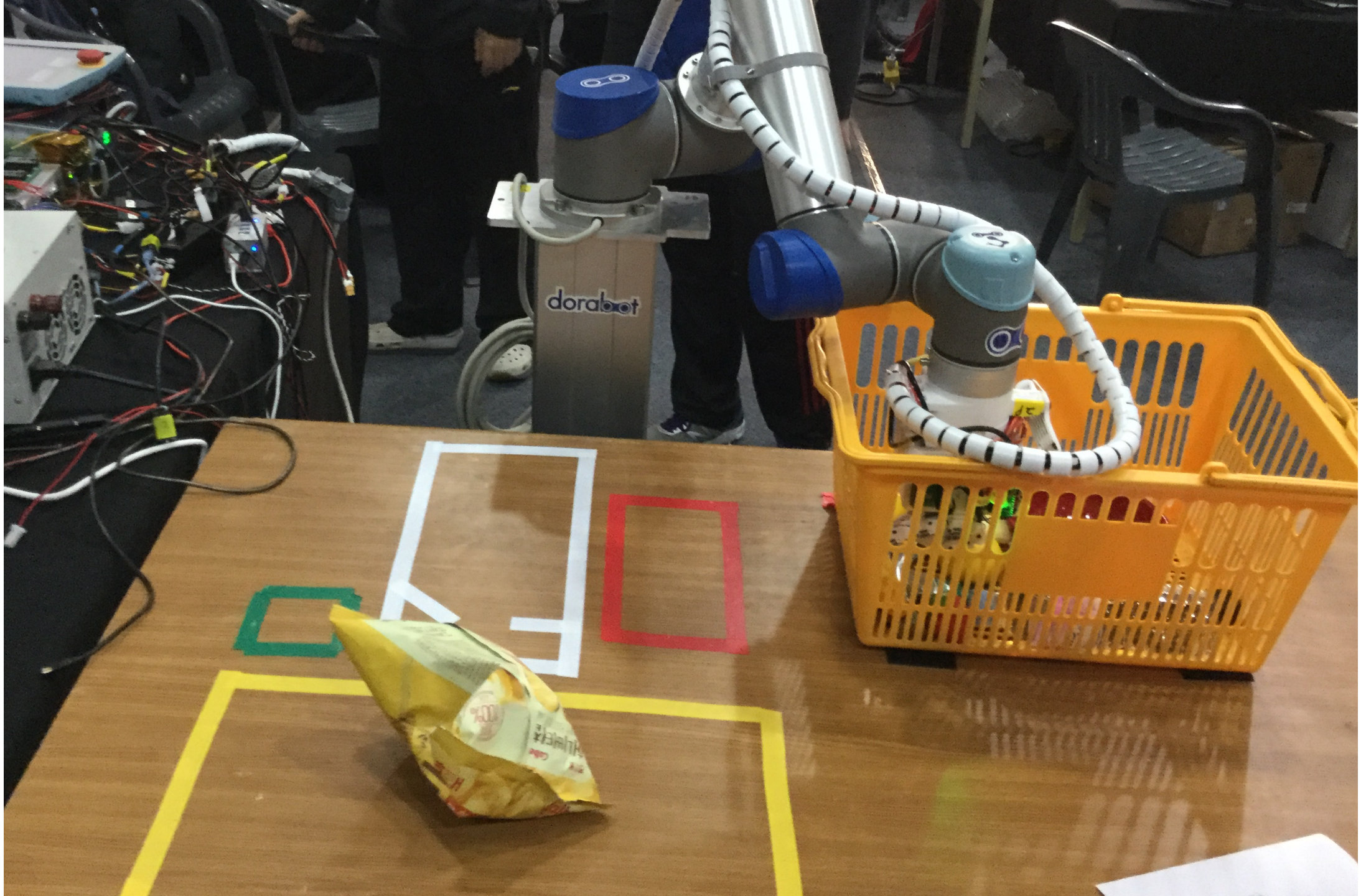


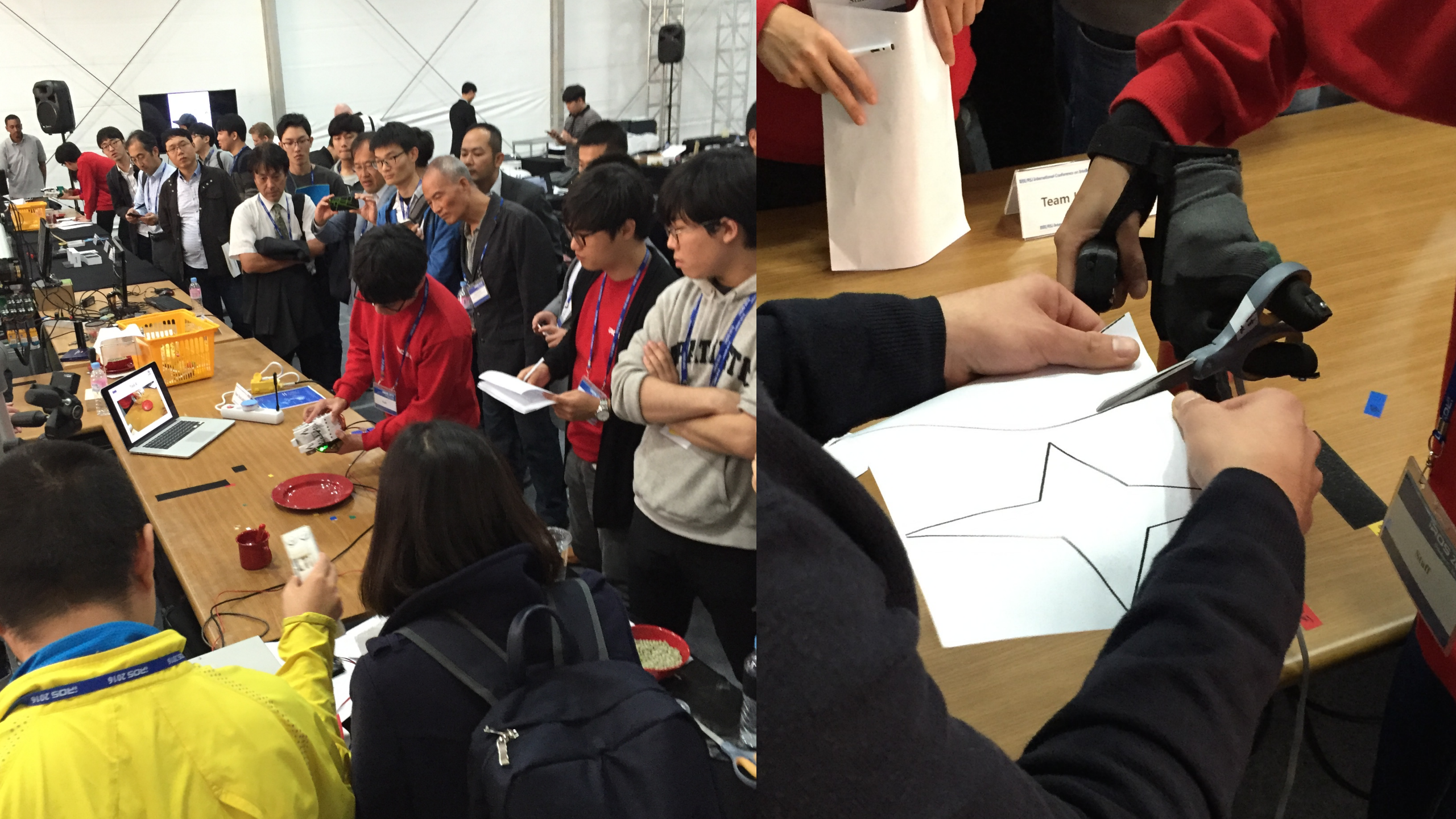


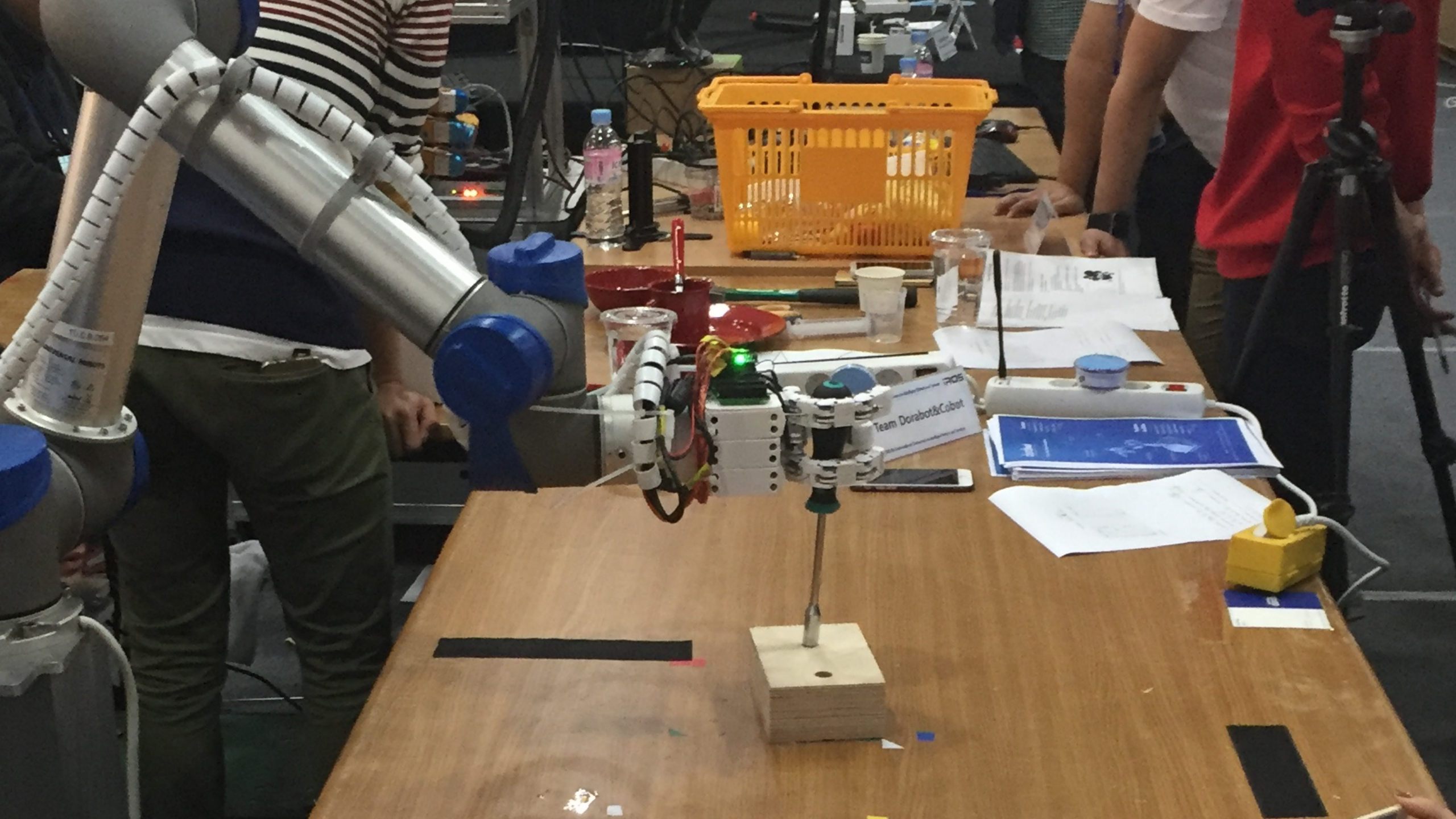



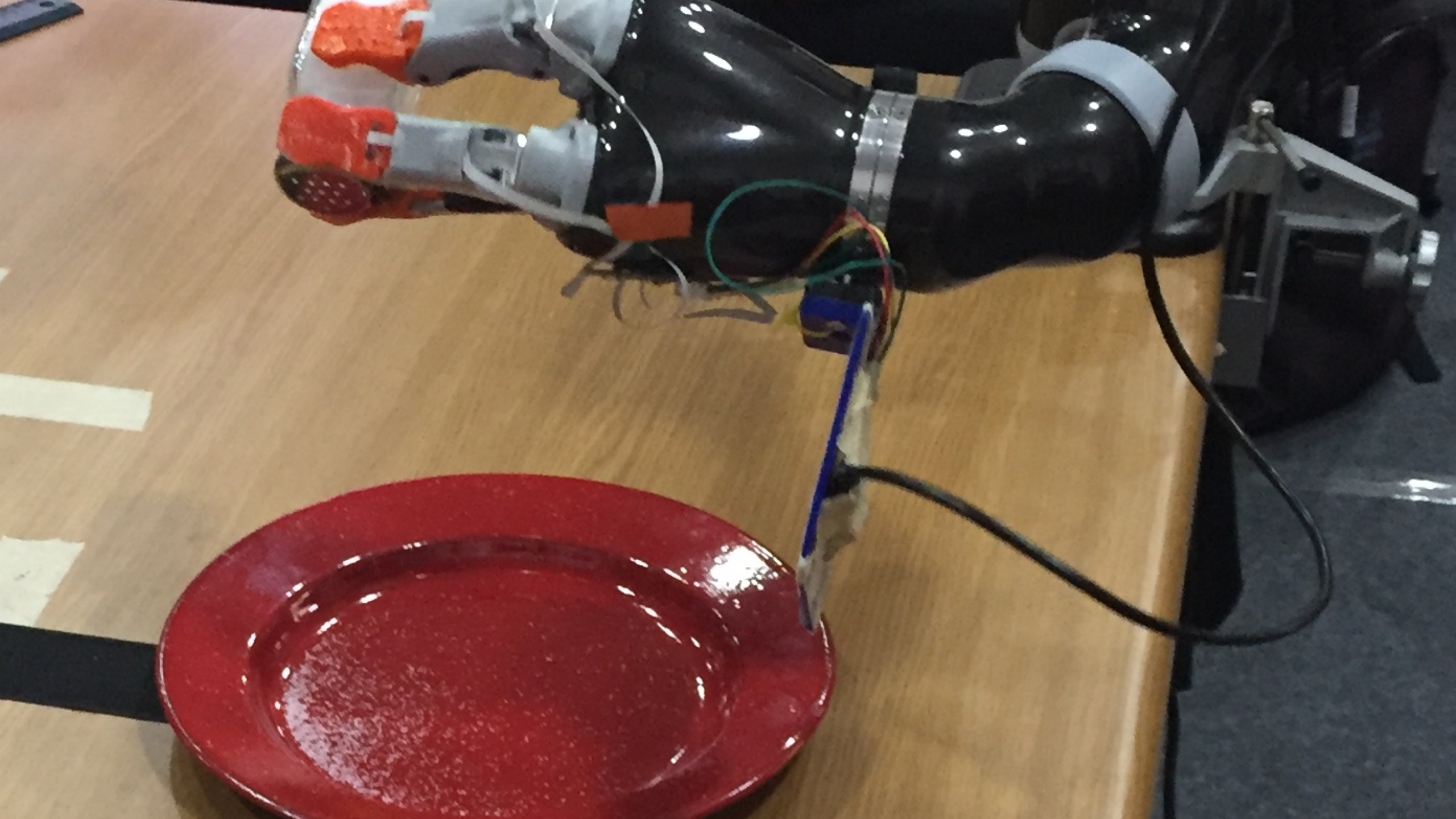


Save Time.
Save Money.
DOLLAR GENERAL
DOLLAR GENERAL
KRAFT


dorabot


Team


Team Dorabot&Cobot



References

1. Lin, Y. and Sun, Y., 2016. Task-oriented grasp planning based on disturbance distribution. In Robotics Research (pp. 577-592). Springer International Publishing.
2. Lin, Y. and Sun, Y., (2015) Grasp Planning to Maximize Task Coverage, Intl. Journal of Robotics Research, 34(9): 1195-1210.
3. Lin, Y., and Sun, Y. (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.
4. Sun, Y., Ren, S., and Lin, Y. (2014) Object-Object Interaction Affordance Learning, Robotics and Autonomous Systems, 62(4), 487-496
5. Dai, W., Sun, Y., Qian, X., (2013) Functional Analysis of Grasping Motion, IROS, pp. 3507-3513.
6. Lin Y., Sun Y. (2013) Grasp Mapping Using Locality Preserving Projections and KNN Regression, IEEE Intl. Conference on Robotics and Automation, pp 1068-1073
7. Lin Y, Sun Y (2011) 5-D Force Control System for Fingernail Imaging Calibration, IEEE Intl. Conference on Robotics and Automation, pp. 1374-1379

Thank You!