

Grasping and Manipulation in Cooking

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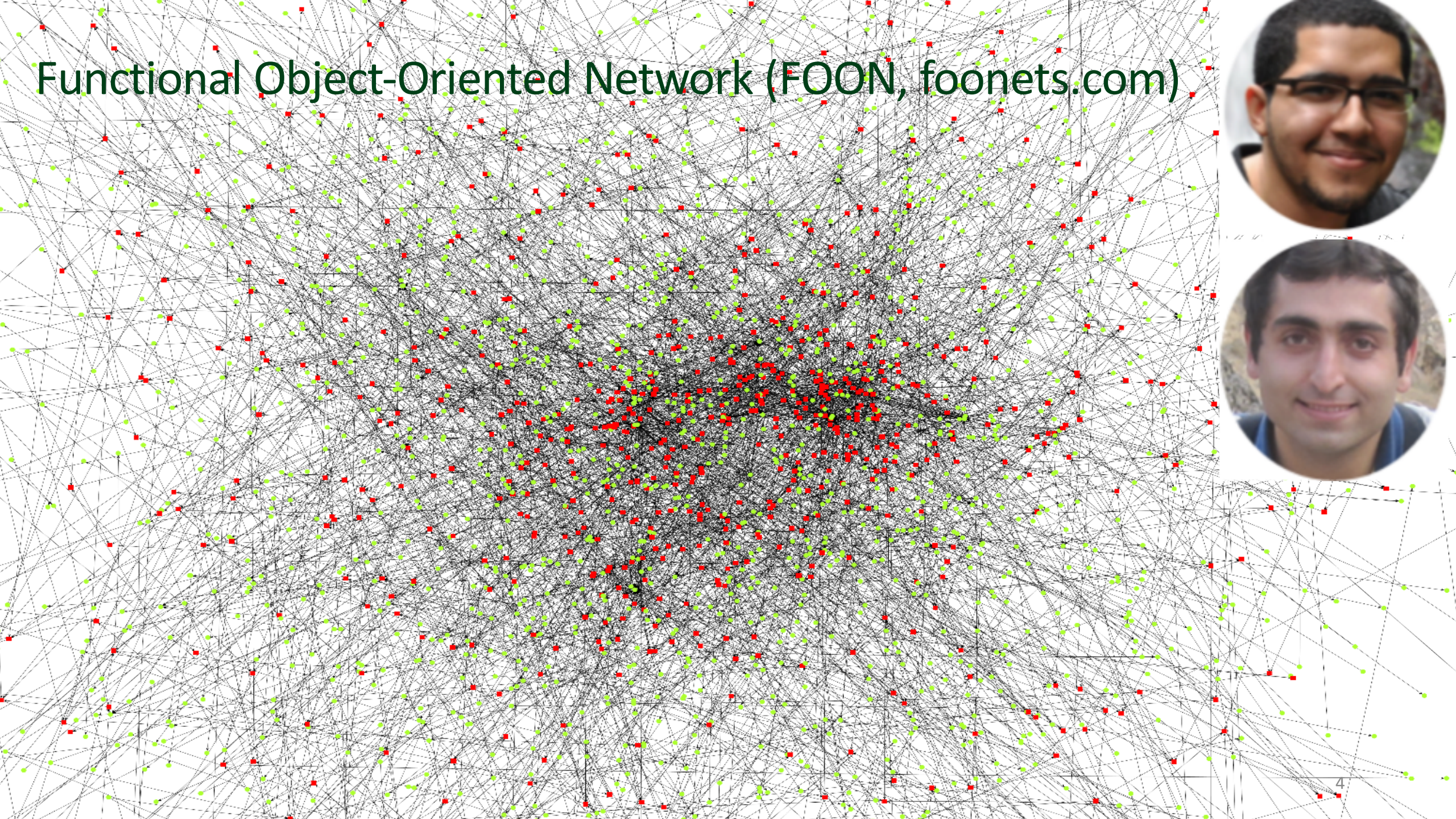
IROS Workshop on Hands in the Real World: Connecting End-Effector Design, Sensitivity, and Behavior, October 1, 2018

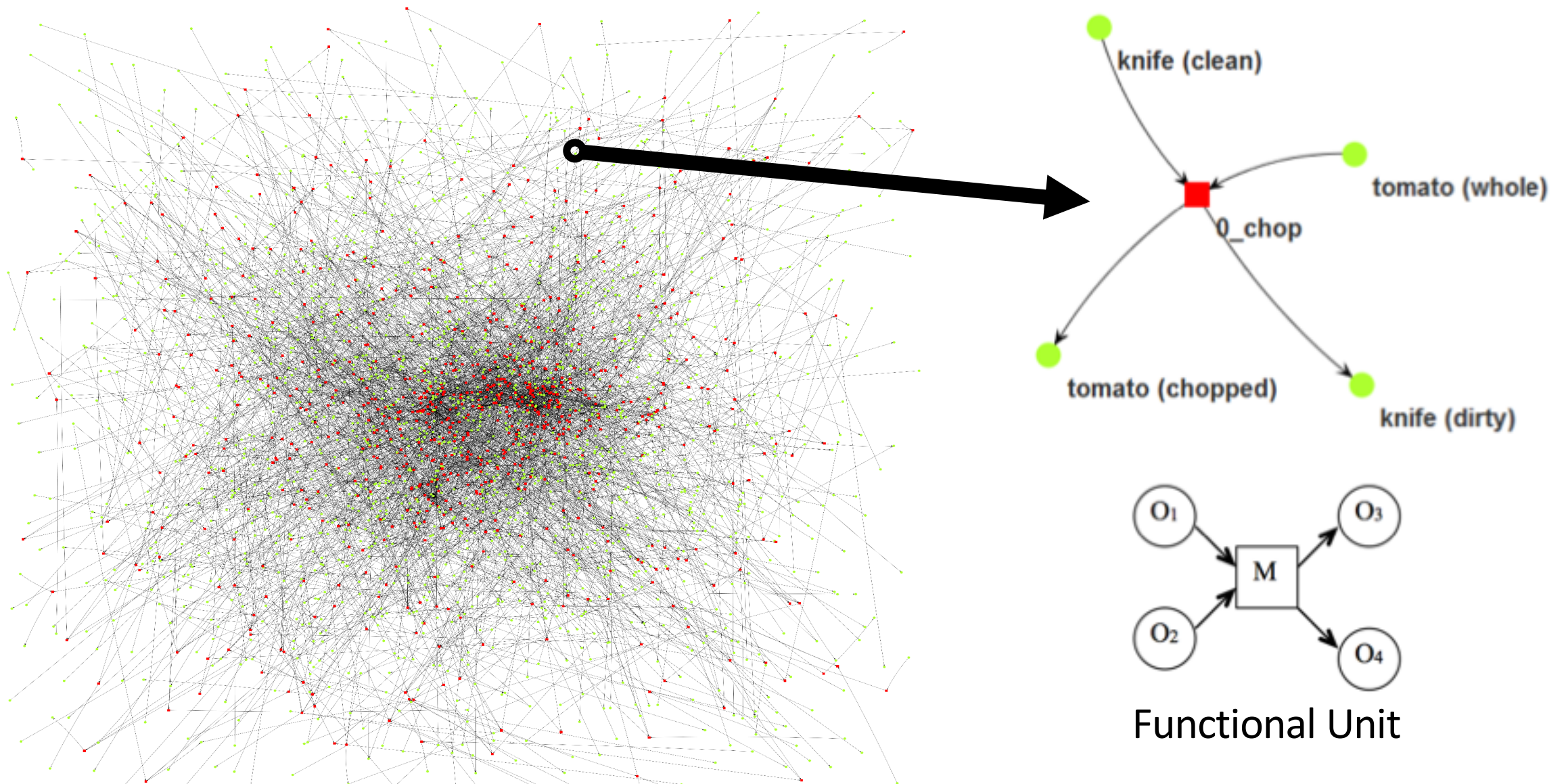


Manipulations in Cooking

Constructing Sub-Graph, an Example

Functional Object-Oriented Network (FOON, foonets.com)

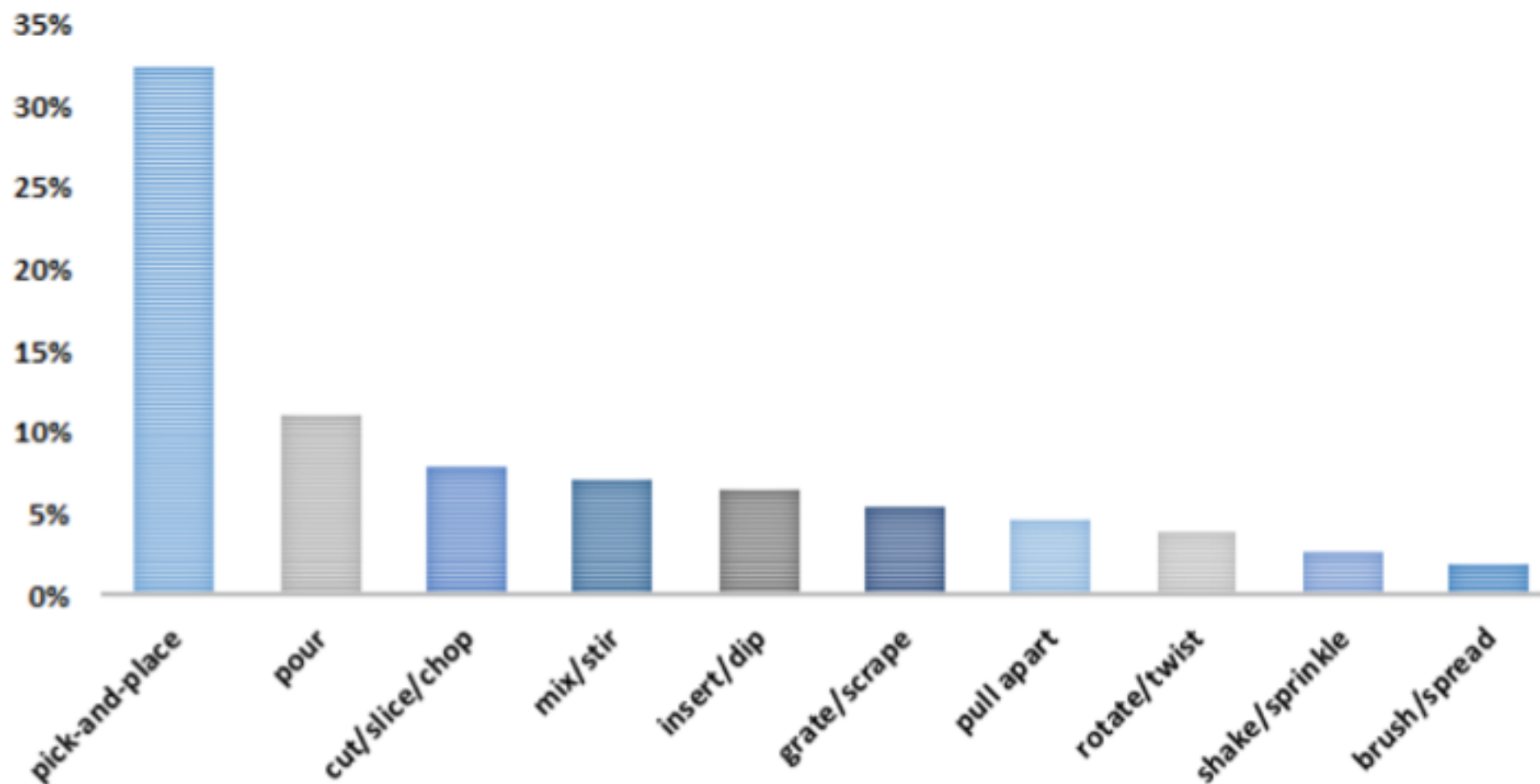




Paulius, D., Jelodar, B., and Sun, Y. (2018) Functional Object-Oriented Network: Construction & Expansion, ICRA 2018, pp 5935-5941.

Paulius, D. Huang, Y., Milton, R., Buchanan, W.D., Sam J., and Sun, Y. (2016) Functional Object-Oriented Network for Manipulation Learning, IROS, 3655-3662. [1,3,8,16,18]

Manipulations in Cooking

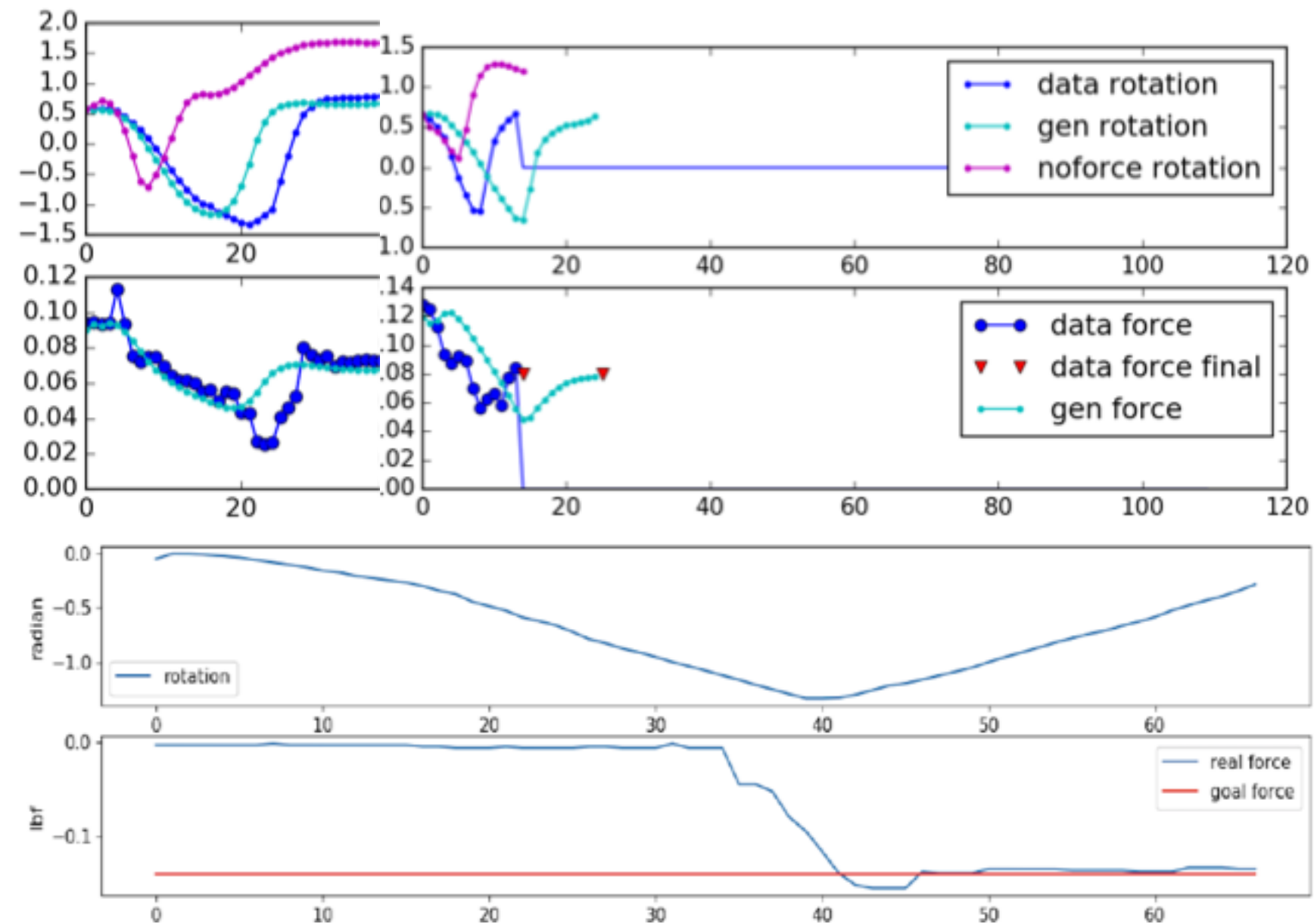


Paulius, D. Huang, Y., Milton, R., Buchanan, W.D., Sam J., and Sun, Y. (2016) Functional Object-Oriented Network for Manipulation Learning, IROS, 3655-3662.

Pouring

- Generate a pouring motion
 - How fast do you pour
 - When to stop and hold
 - When to recover
 - How fast do you recover
- Decided by
 - How much in the pouring cup
 - How much need to be poured
 - Sizes of pouring and receiving cups
 - Material





Huang, Y. and Sun, Y. (2017). Learning to Pour, IROS, pp 7005-7010

Huang, Y. and Sun, Y. (2015) Generating Manipulation Trajectories Using Motion Harmonics, IROS, 4949-4954. [2,4,5,⁸,13]



Robotic Grasping and Manipulation Competition IROS 2016 & 2017

Sun, Yu, and Joe Falco, eds. *Robotic Grasping and Manipulation: First Robotic Grasping and Manipulation Challenge, RGMC 2016, Held in Conjunction with IROS 2016, Daejeon, South Korea, October 10–12, 2016, Revised Papers*. Vol. 816. Springer, 2018.

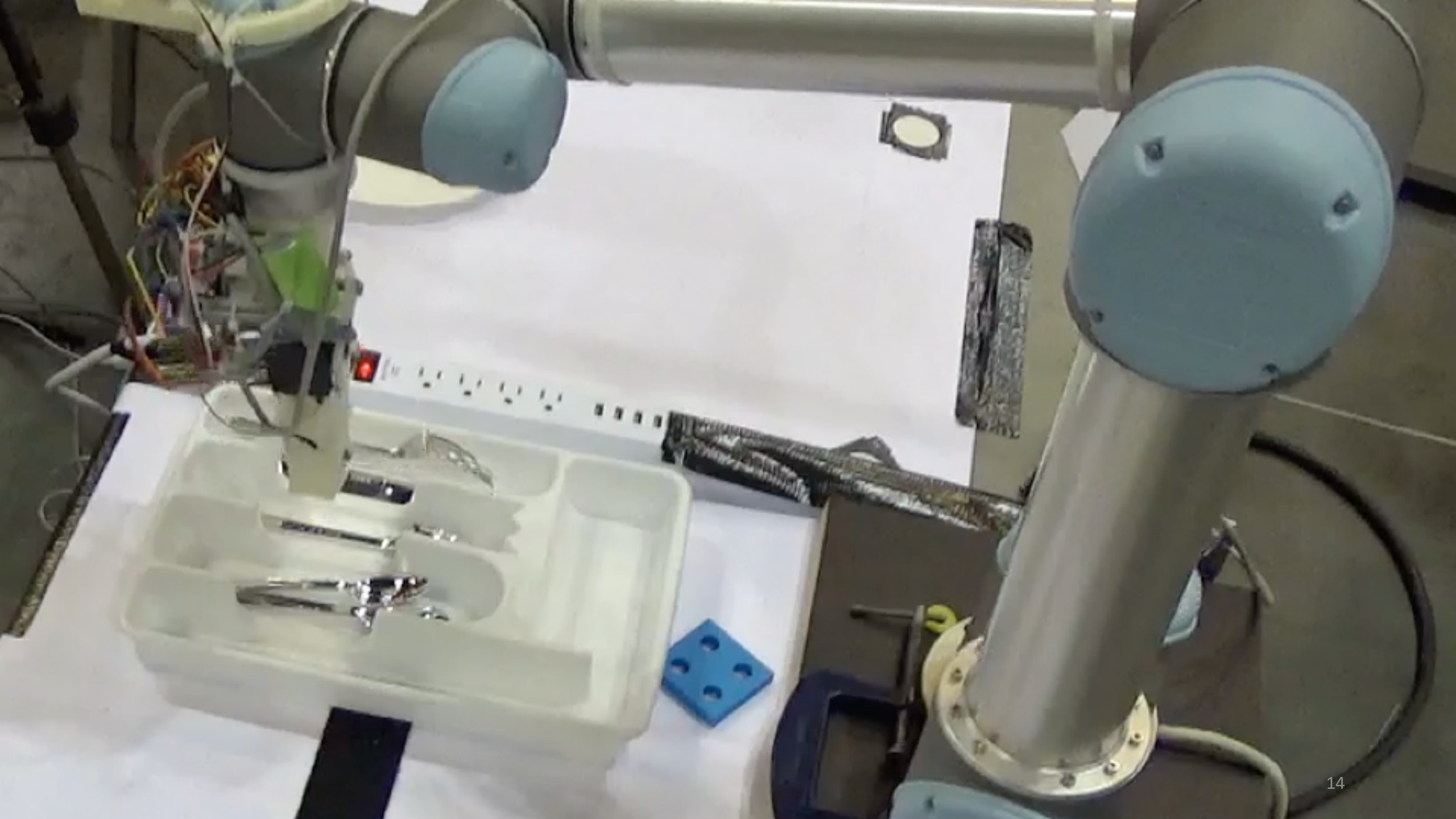
- Use a spoon to pick up peas
- Hang towel on rack
- Use a spoon to stir water in a cup
- Shake salt shaker
- Plug into a socket
- Hammer a nail
- Transfer straw into a to-go cup with lid
- Putting on or removing bolts from nuts with a nut driver
- Extend and press syringe



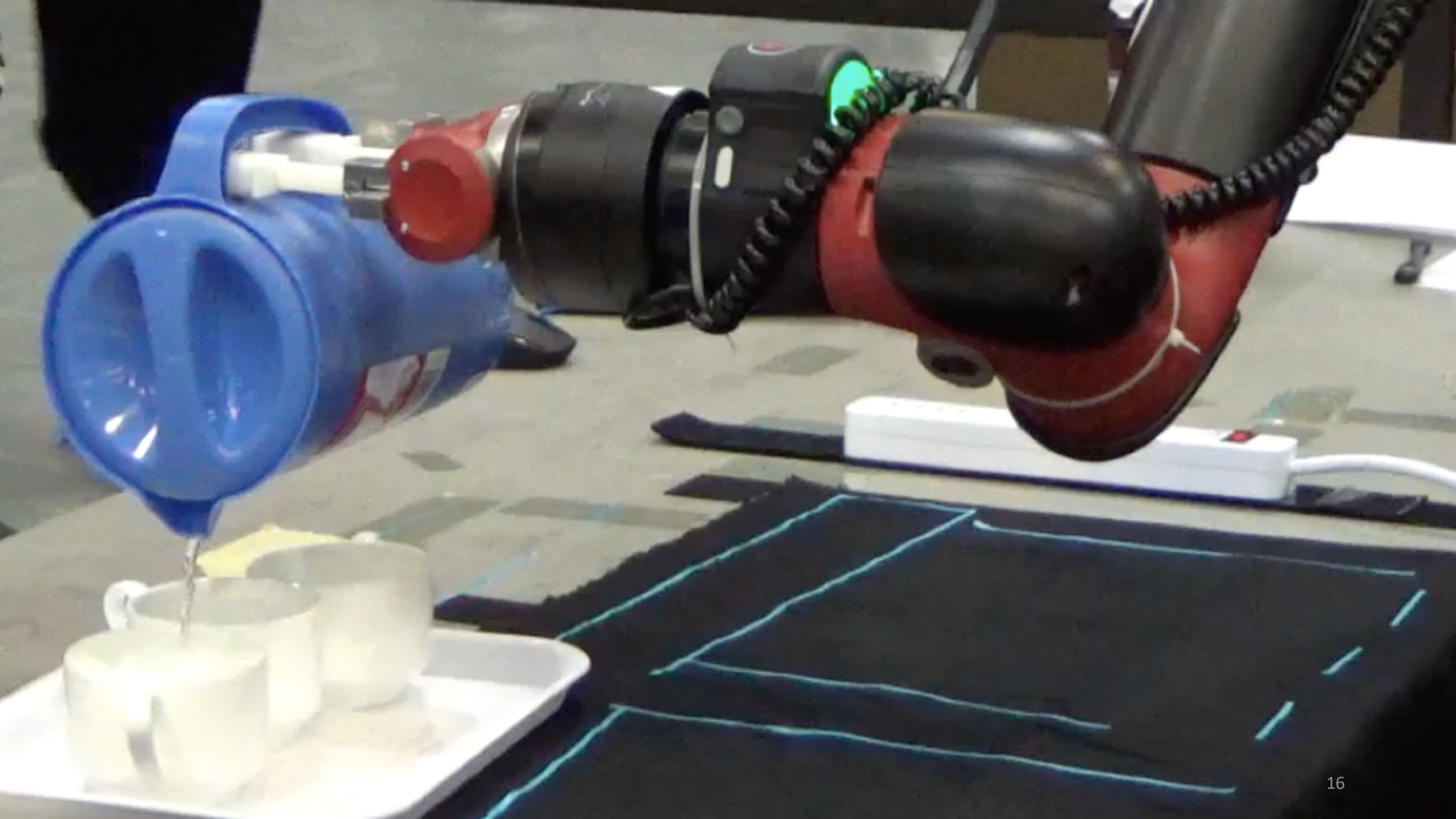
- Transfer a cup on its saucer
- Arrange silverware
- Stir water in a cup
- Pour water into a cup
- Plug into a socket
- Tear away one piece of paper towel
- Play sorting board
- Hammer a nail
- Transfer straw into a to-go cup with lid
- Open a bottle with a locking safety cap

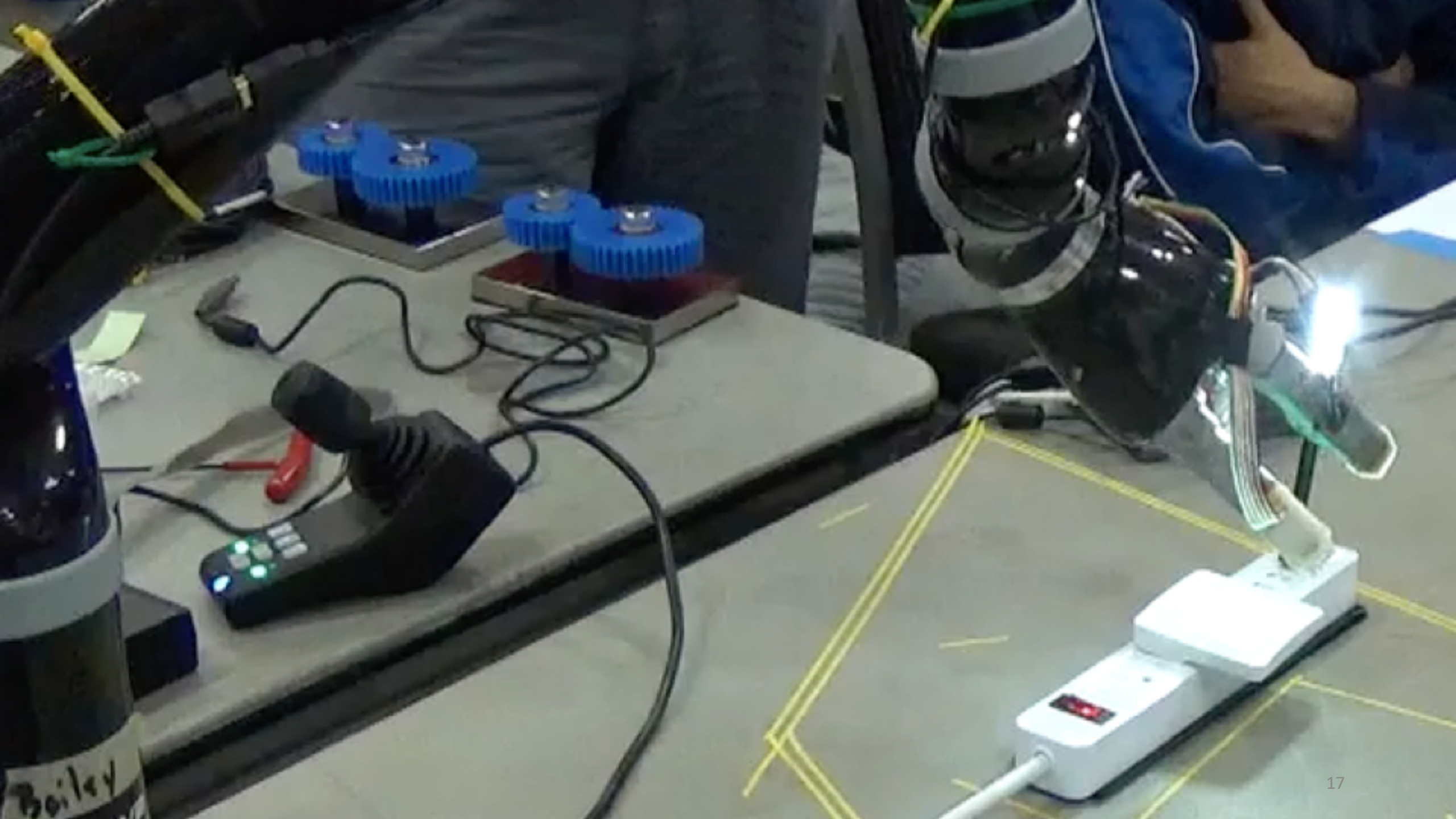


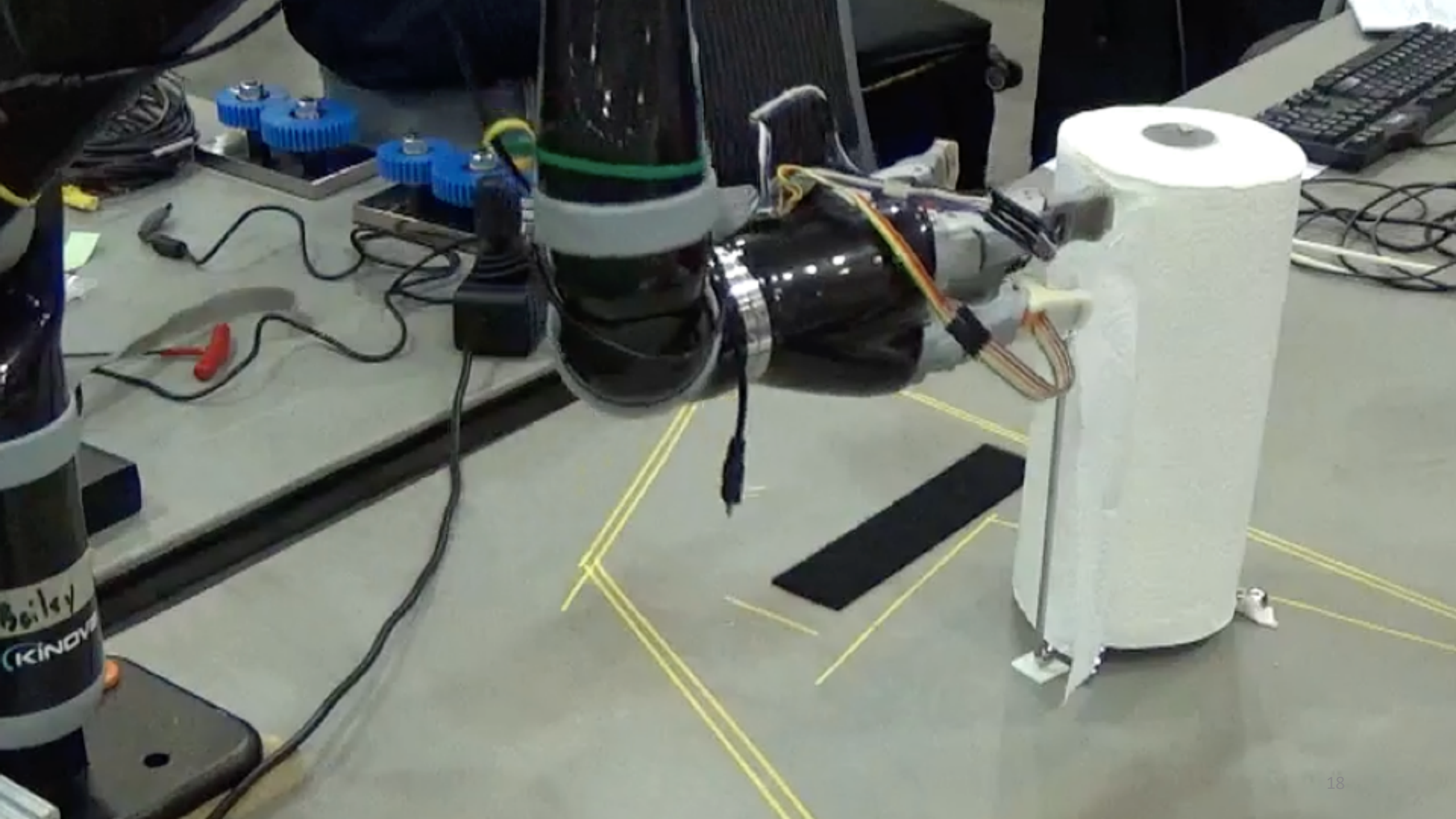




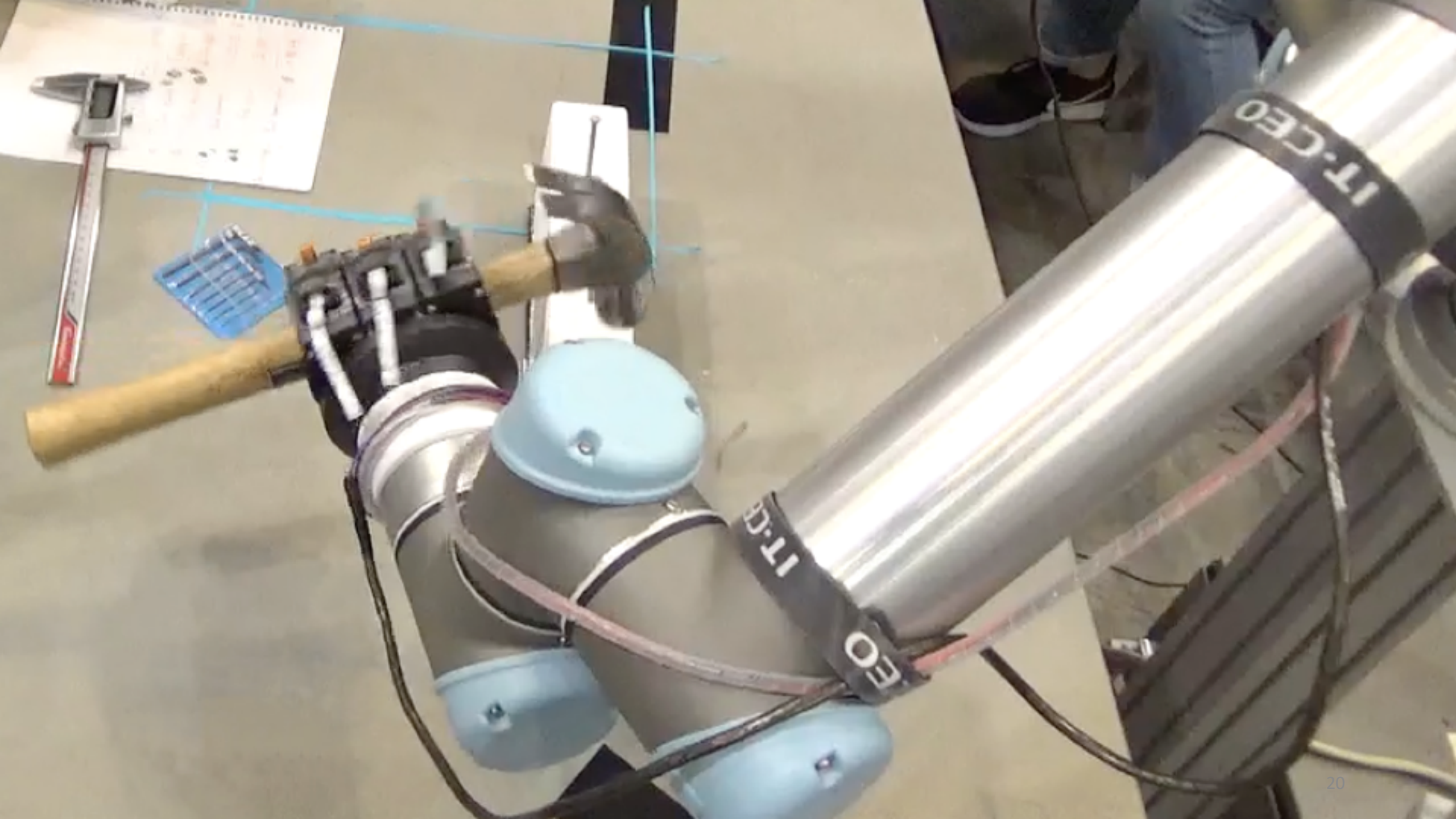


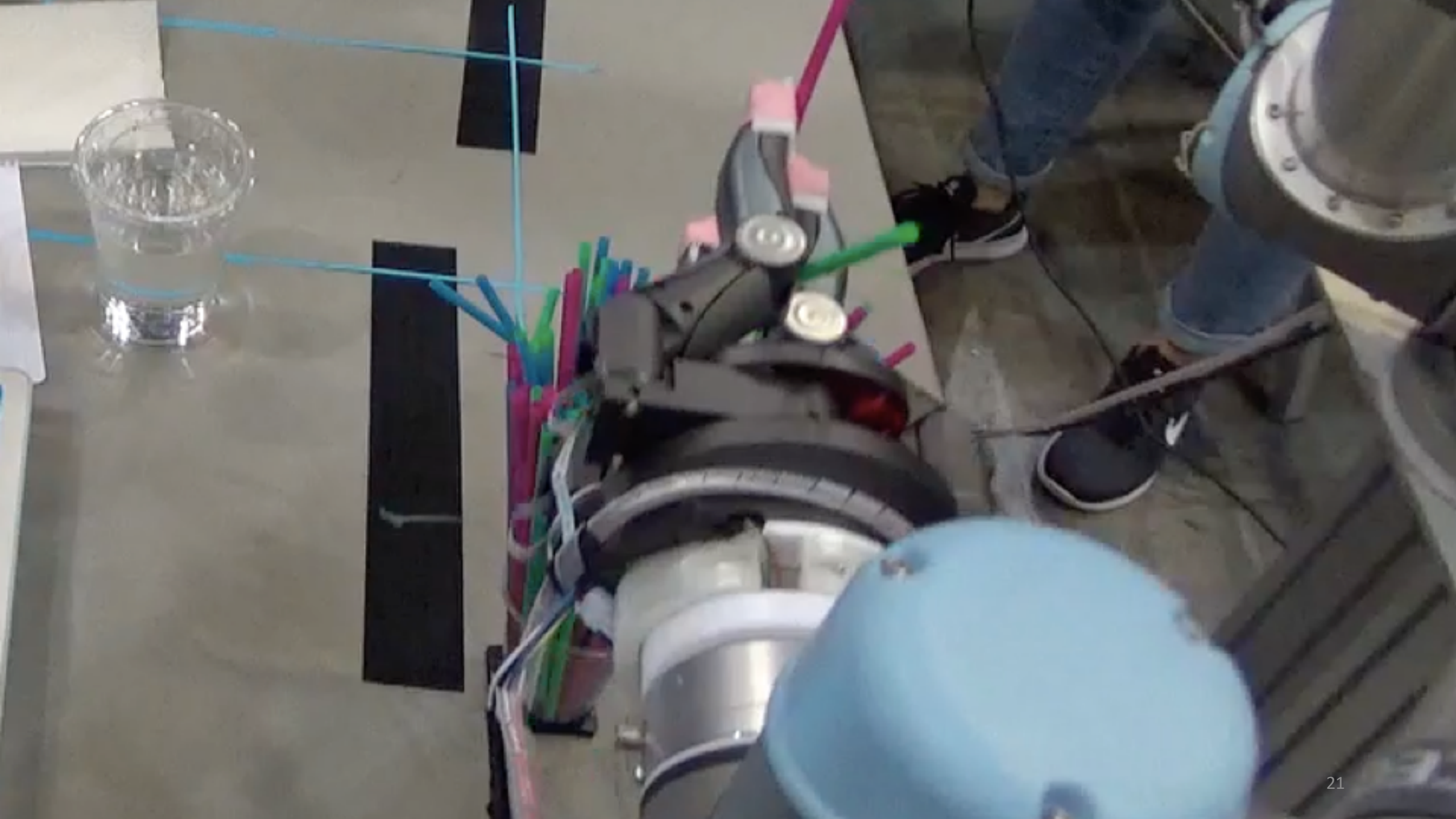


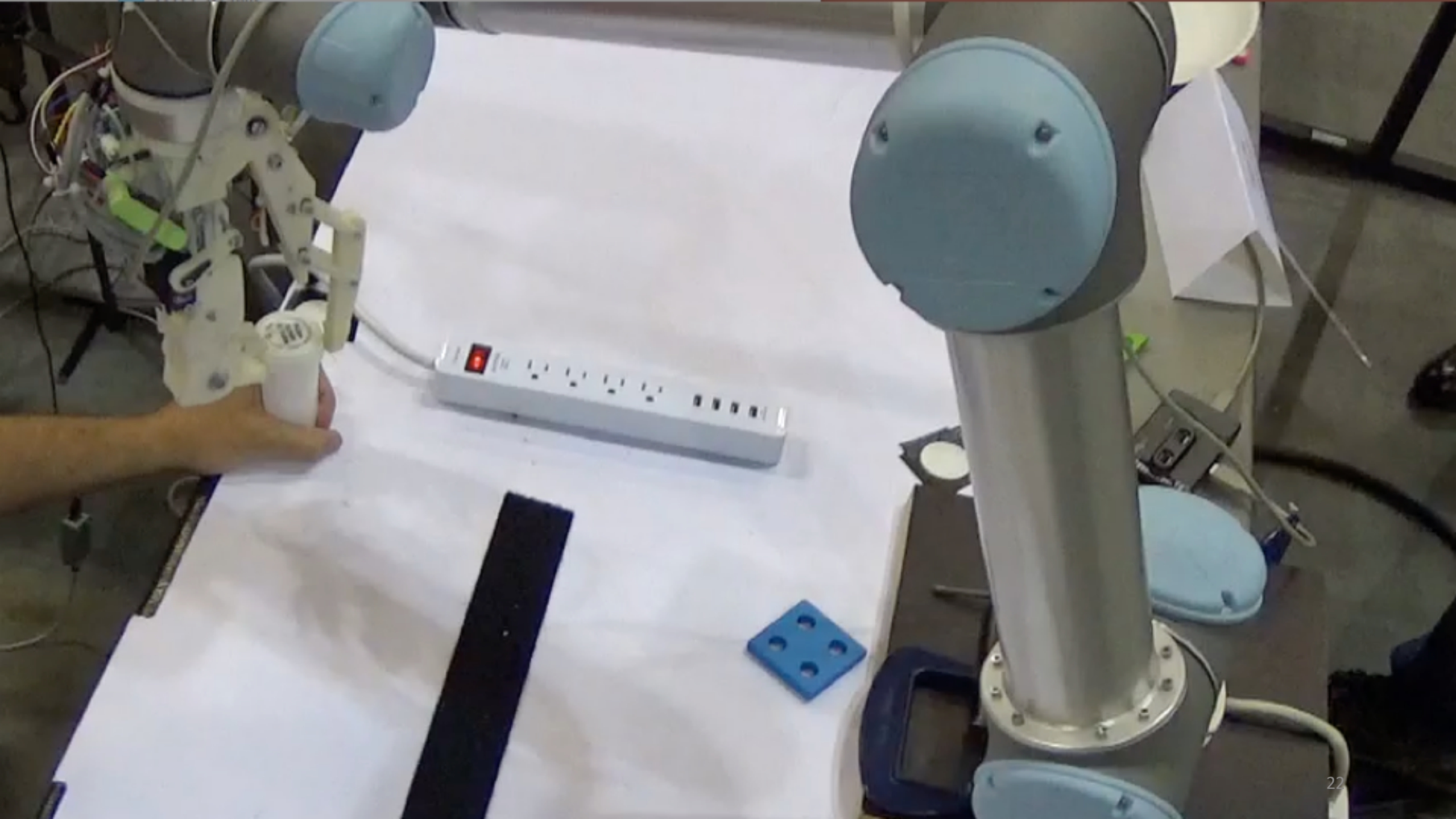












Result Summary

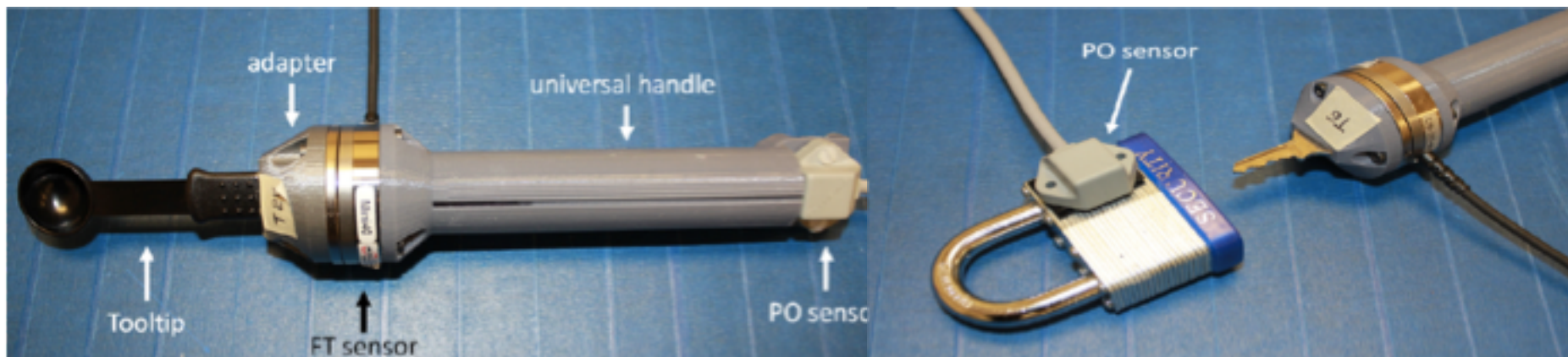
- Tasks successfully performed by at least one team after multiple attempts
 1. Transfer a cup on its saucer
 3. Stir water in a cup
 5. Plug into a socket
 7. Play sorting board
 8. Hammer a nail
 9. Transfer straw into a to-go cup with lid
 10. Open a bottle with a locking safety cap
- Tasks that no team could successfully complete
 2. Arrange silverware
 4. Pour water into a cup
 6. Tear away one piece of paper towel

Combined Scores of Six Teams by Task

1. Transfer a cup on its saucer - 20/60
2. Arrange silverware – 26/90
3. Stir water in a cup – 20/60
4. Pour water into a cup – 0/180
5. Plug into a socket – 40/120
6. Tear away one piece of paper towel – 10/120
7. Play sorting board – 65/180
8. Hammer a nail – 30/180
9. Transfer straw into a to-go cup with lid – 120/180
10. Open a bottle with a locking safety cap – 190/240

Physically Interactive Manipulations

Motion Learning Dataset



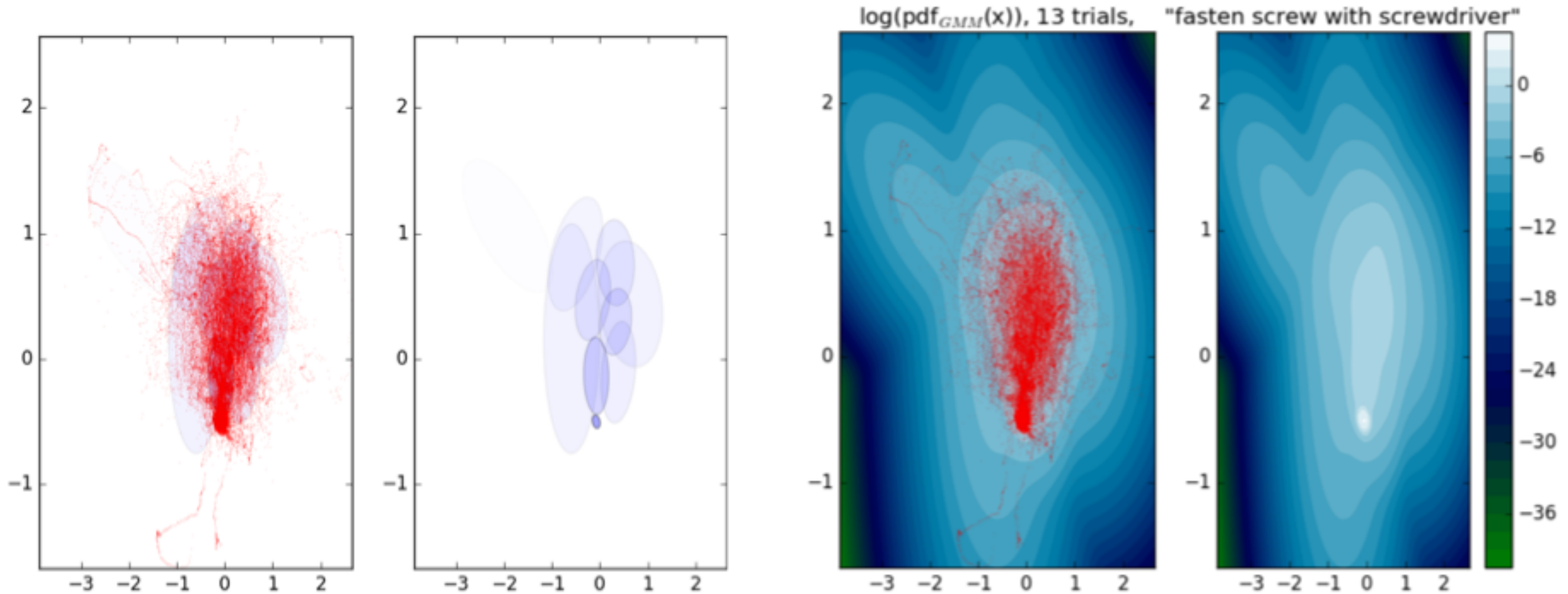
30+ motions:
pour, mix, sprinkle, shake, spear,
stir, brush, scrape, peel, slice, flip,
scoop, brush, spread ...

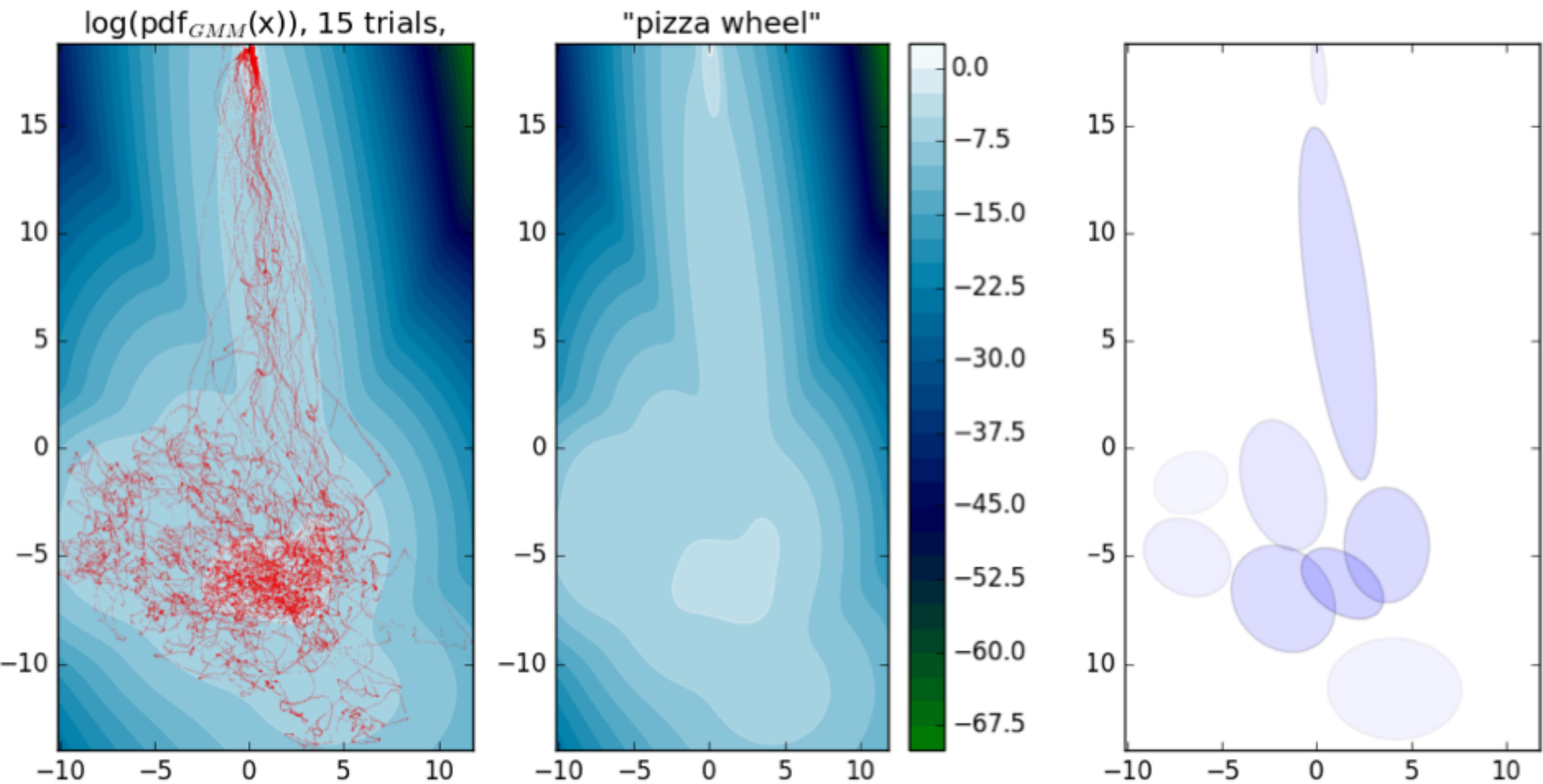
Huang, Y. and Sun, Y. (2018) A Dataset of Daily Interactive Manipulation, International Journal of Robotics Research (Revision)

Dataset Download: http://roal.cse.usf.edu/datasets_manipulation.html

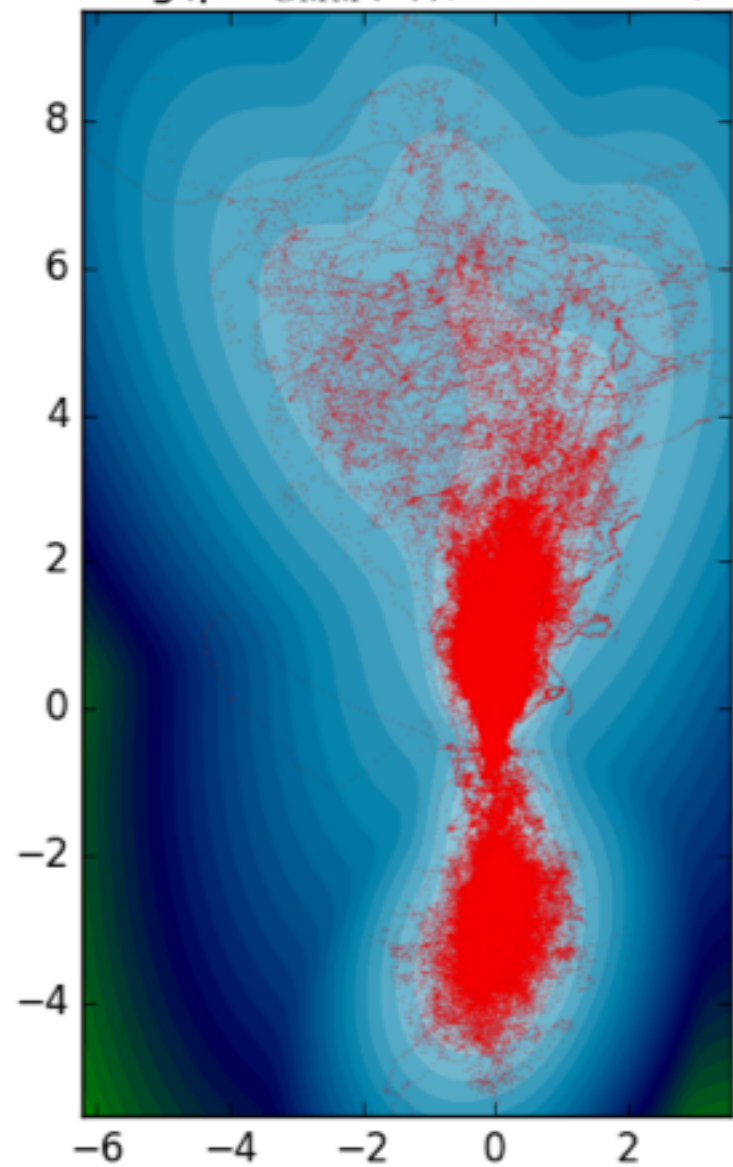
Huang, Y, Bianchi, M, Liarokapis, M and Sun, Y (2016) Recent Data Sets on Object Manipulation: A Survey, Big Data, 4(4):197-216.

Force and Torque Distribution GMM

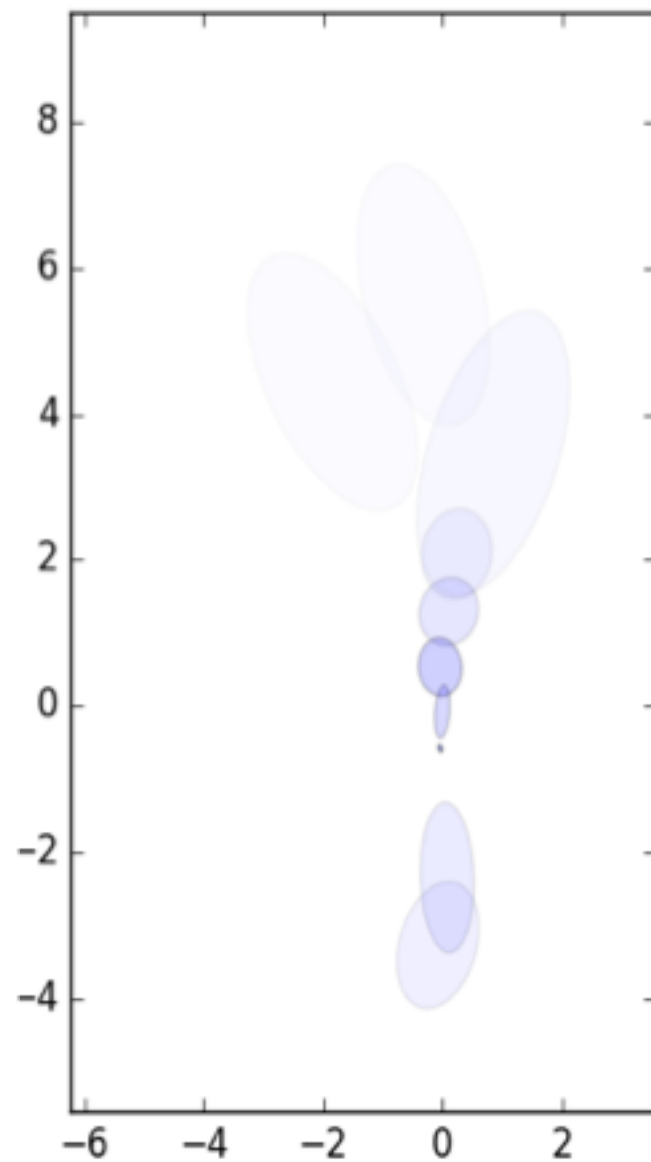
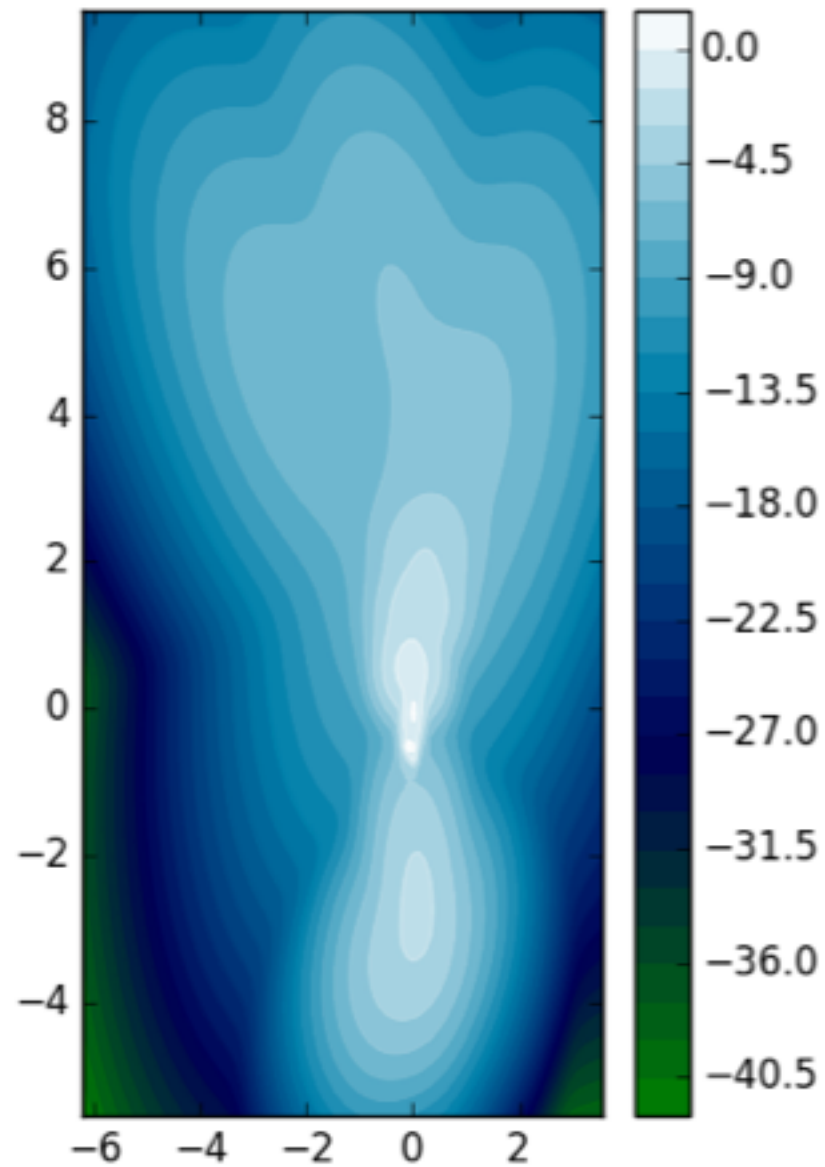


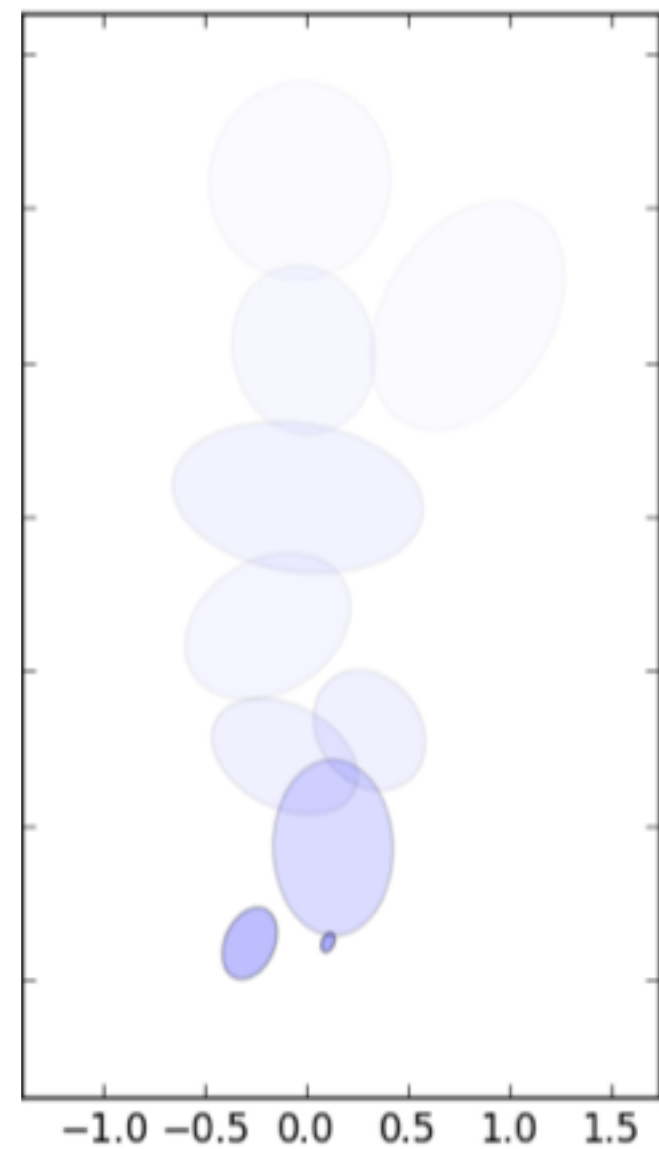
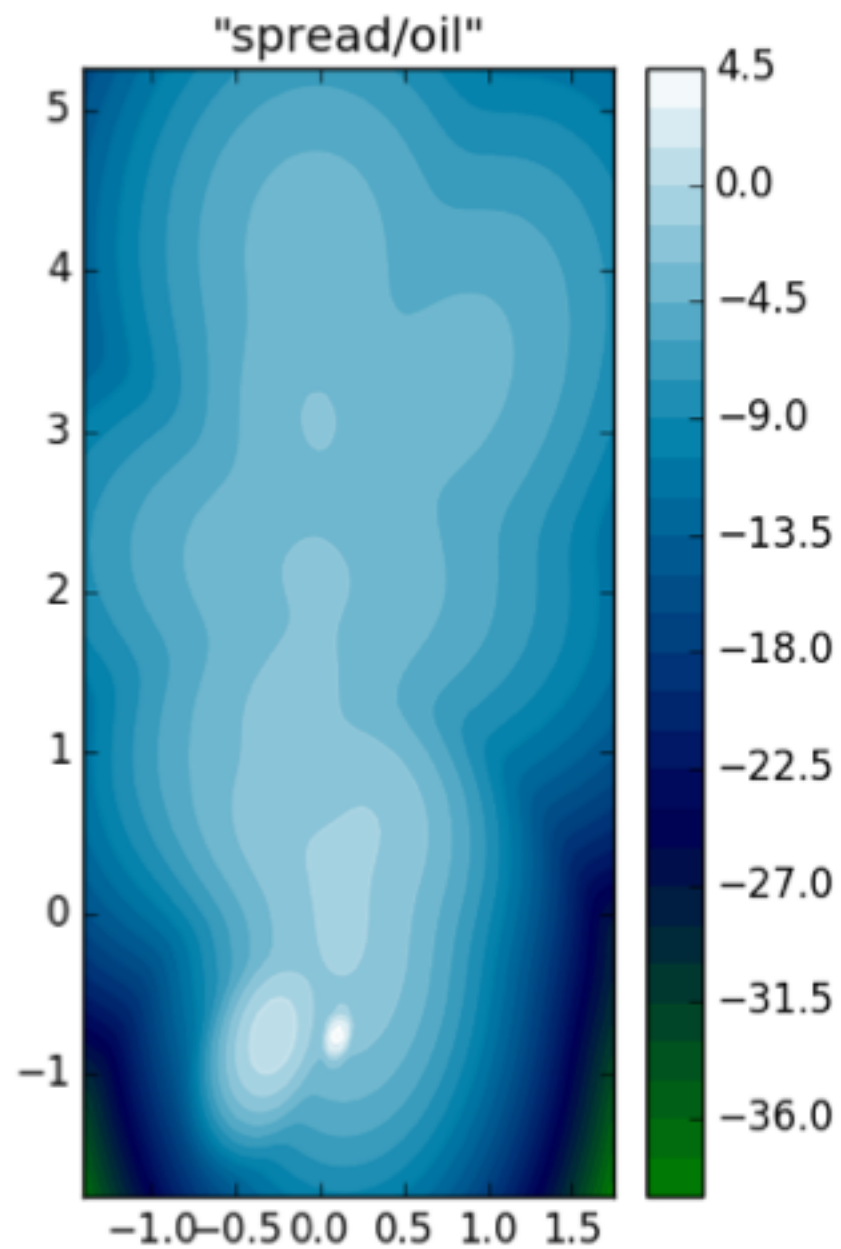
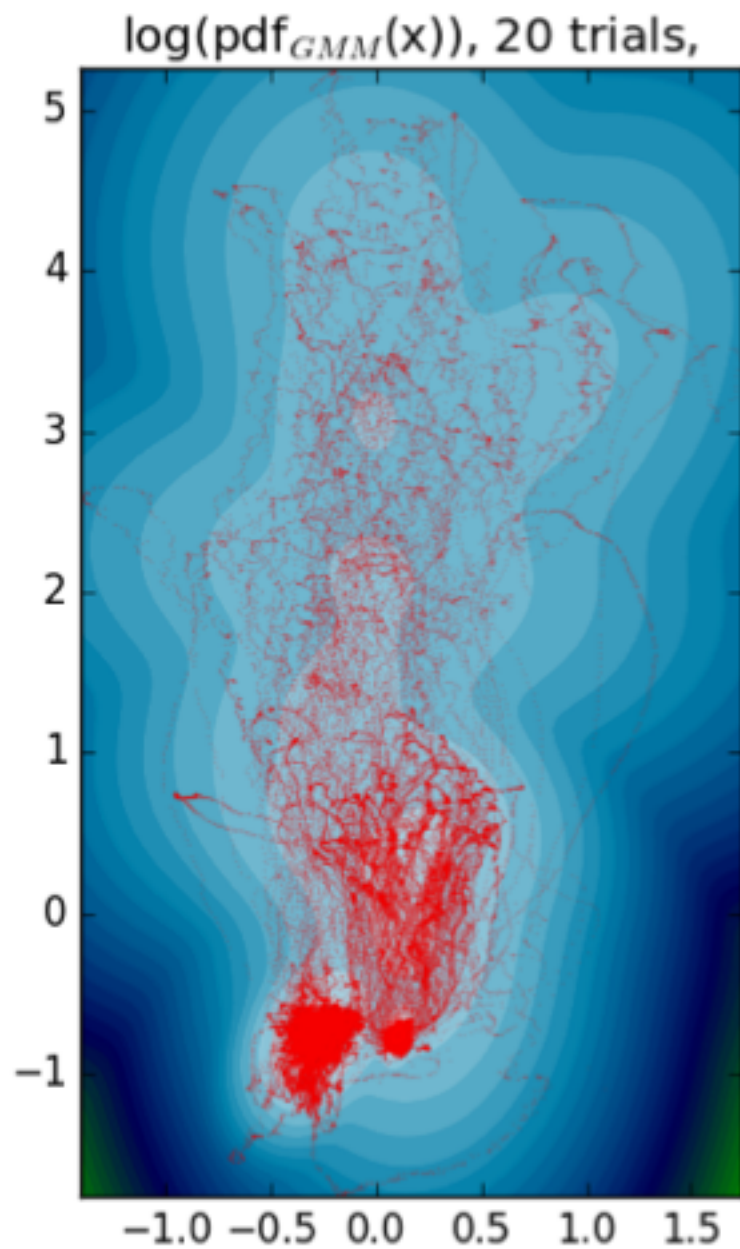


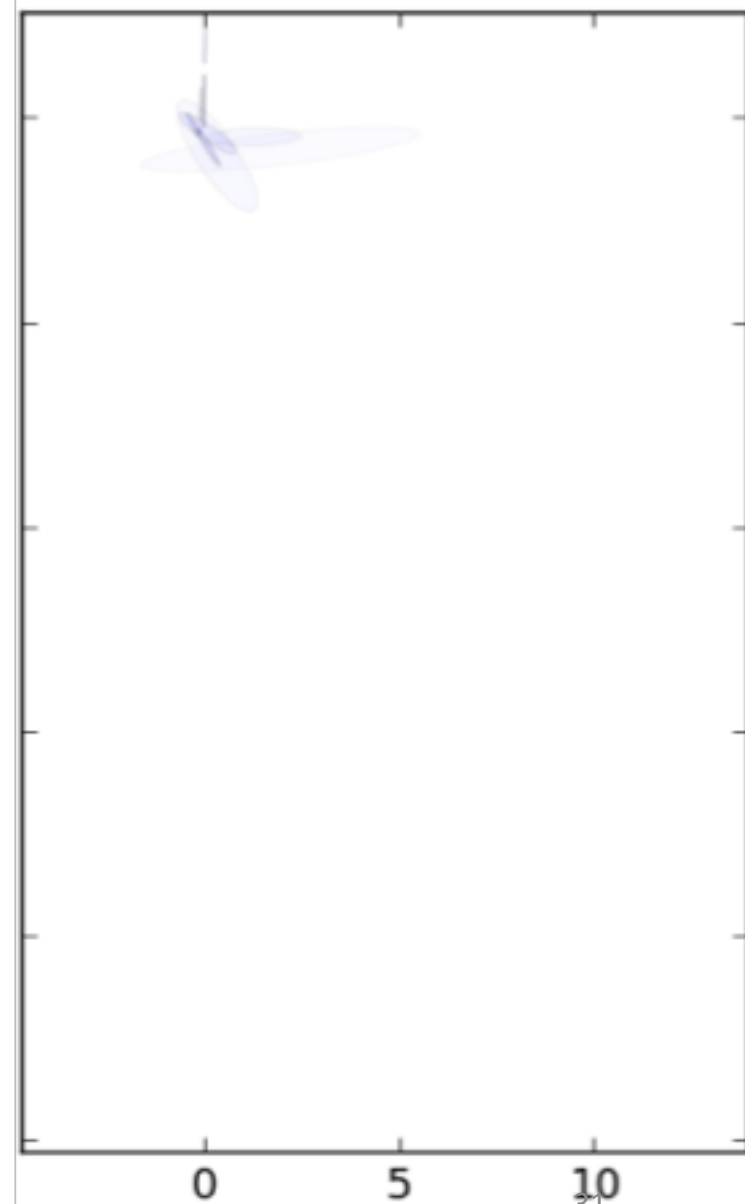
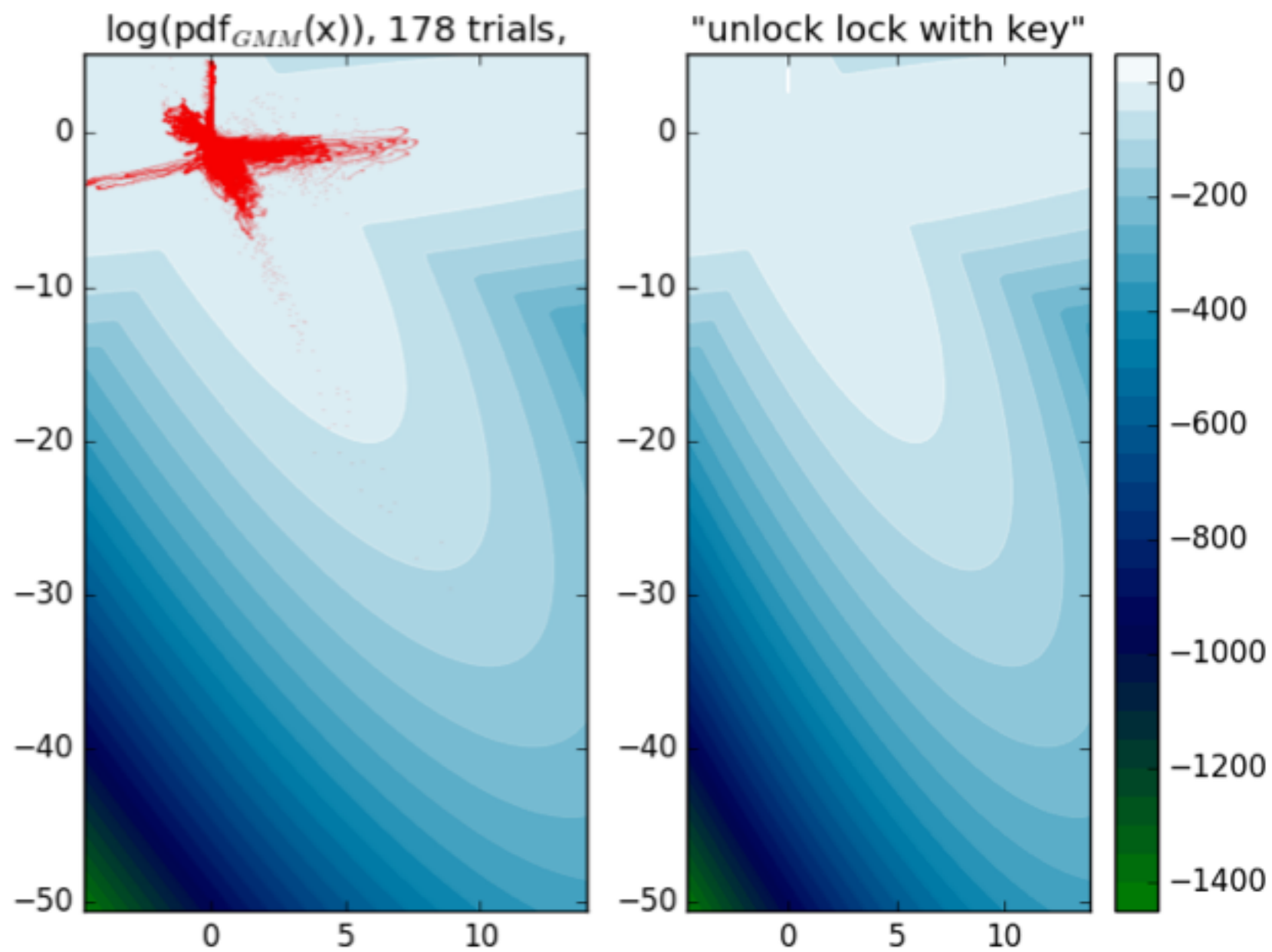
$\log(\text{pdf}_{GMM}(x))$, 115 trials,

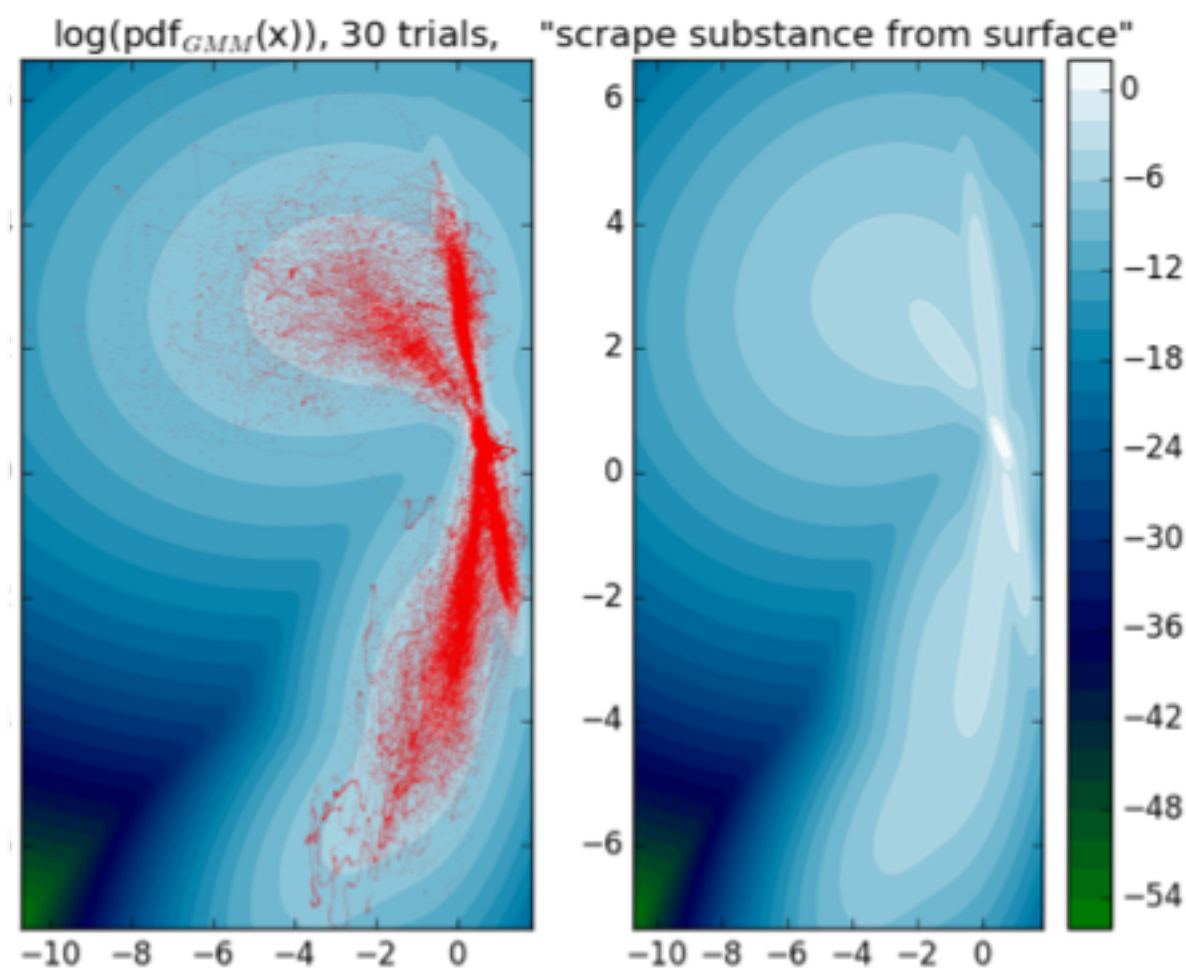
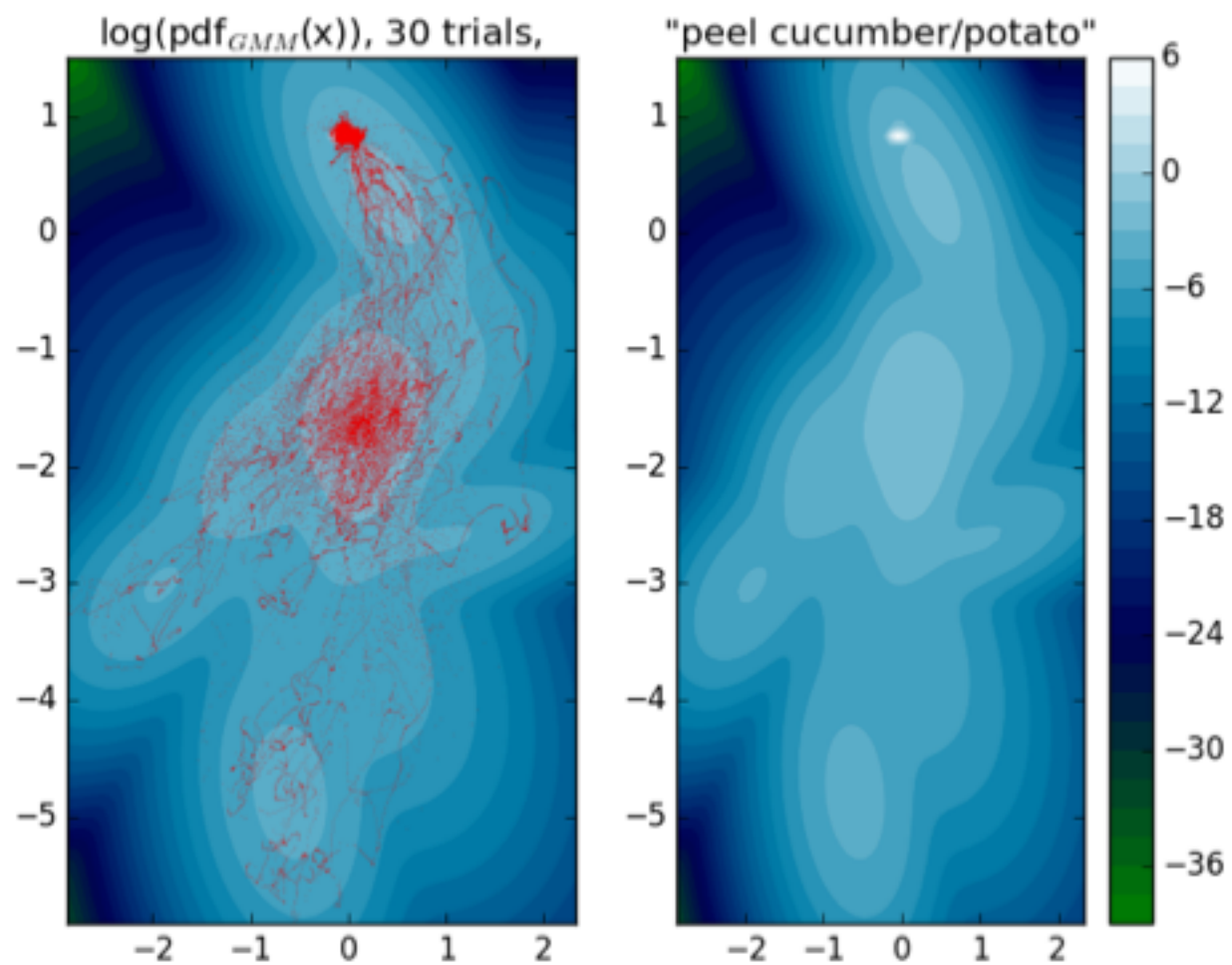


"use file to file wooden block"







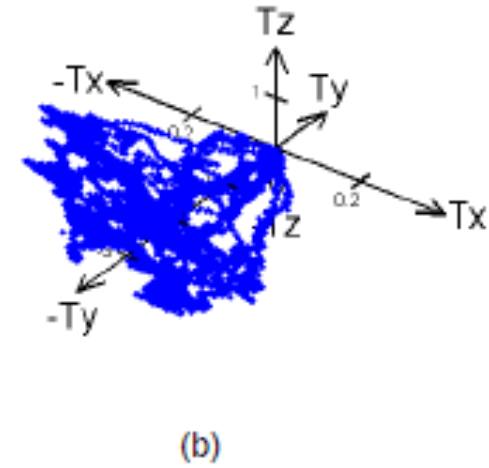
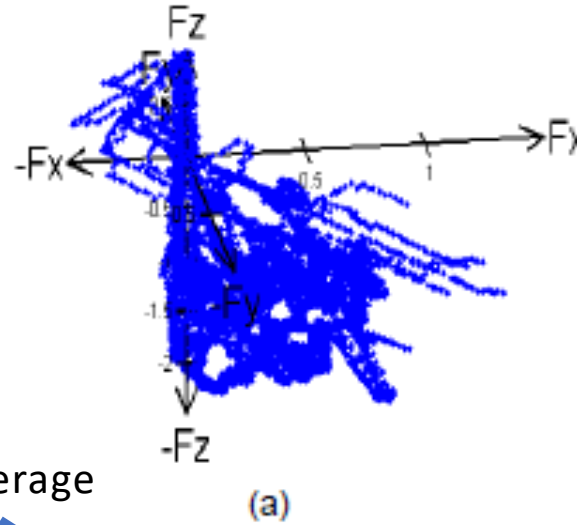


Use a Knife

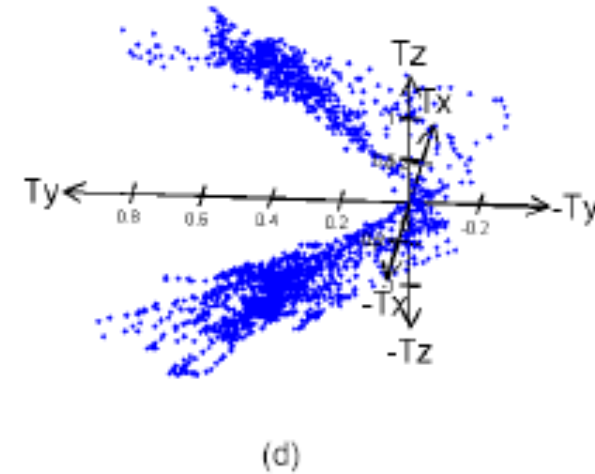
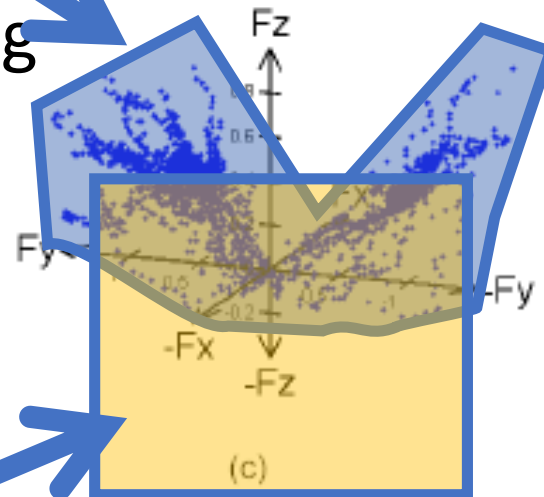
Task 1: cutting



Task Coverage



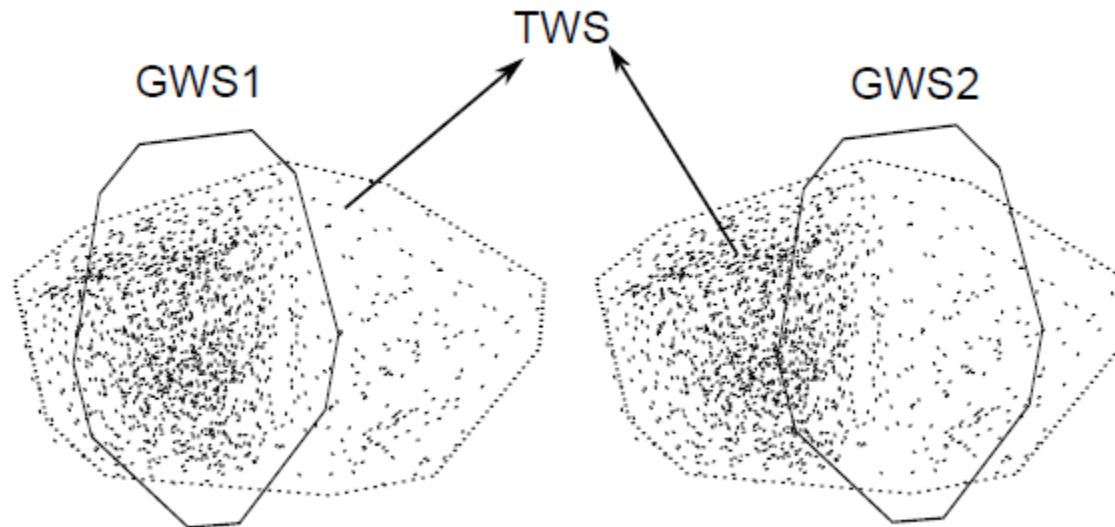
Task 2: butter spreading



Quality Measure: Task Wrench Coverage

- Random in task: density of the task wrench samples
- The count of task wrench observations in the TWS that are covered by GWS
- The count of the total task wrench observations in the TWS

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



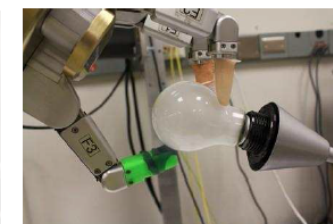
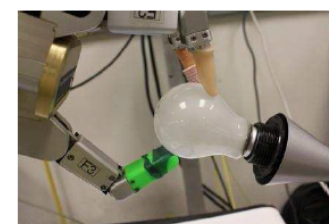
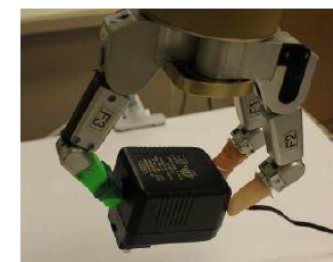
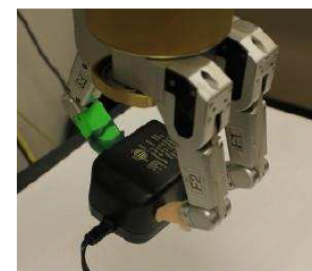
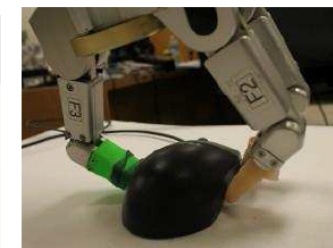
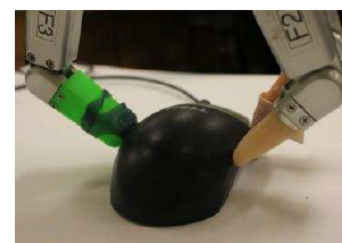
Grasp search to maximize
the task coverage

Task-Oriented Grasping



Our approach

Force-closure approach



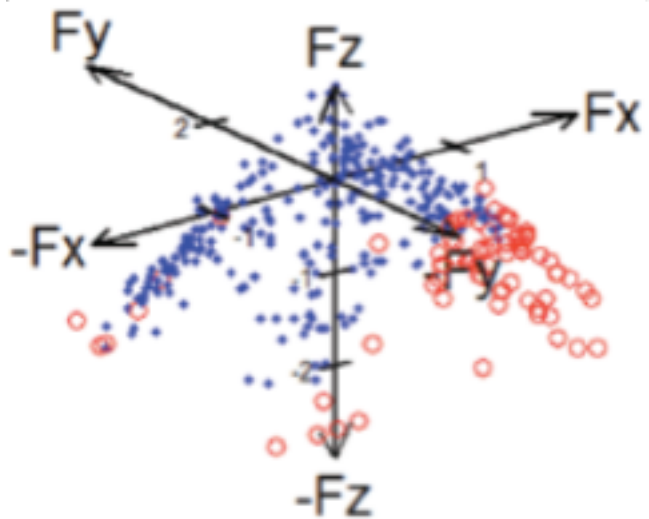
Task	Success Rate of Task Disturbance Based Grasp Planning	Success Rate of non-task oriented Grasp Planning
Task 1	60%	40%
Task 2	80%	70%
Task 3	70%	20%
Overall	70%	43.3%

Lin, Y. and Sun, Y., (2015) Grasp Planning to Maximize Task Coverage, Intl. Journal of Robotics Research, 34(9): 1195-1210.

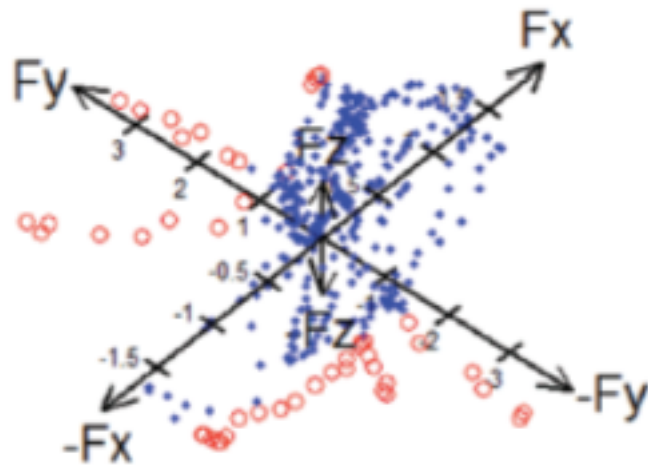
Lin, Y., and Sun, Y. (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.

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

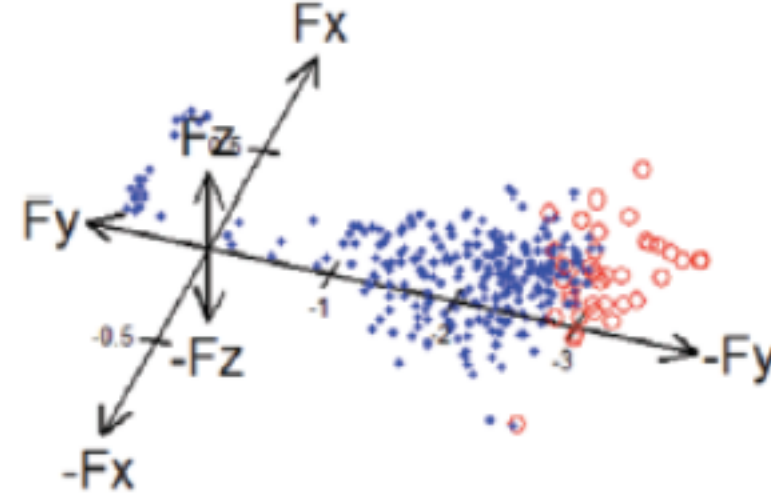
Task 1



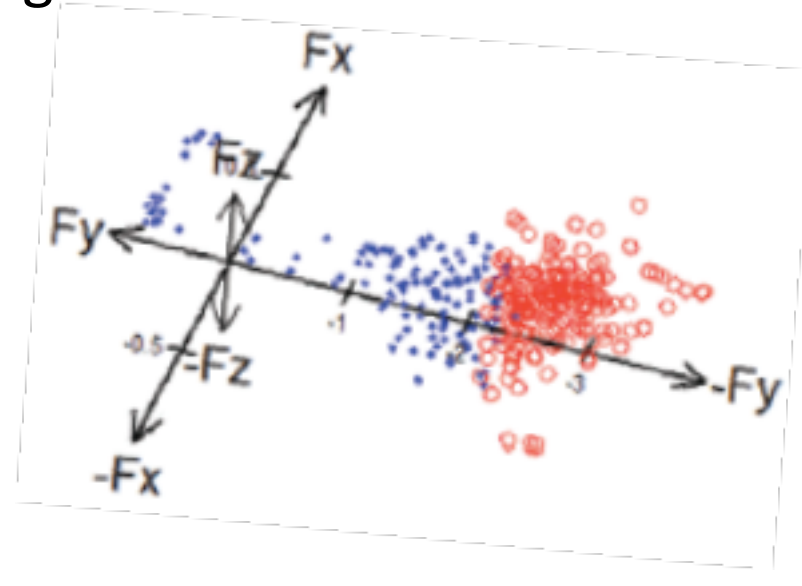
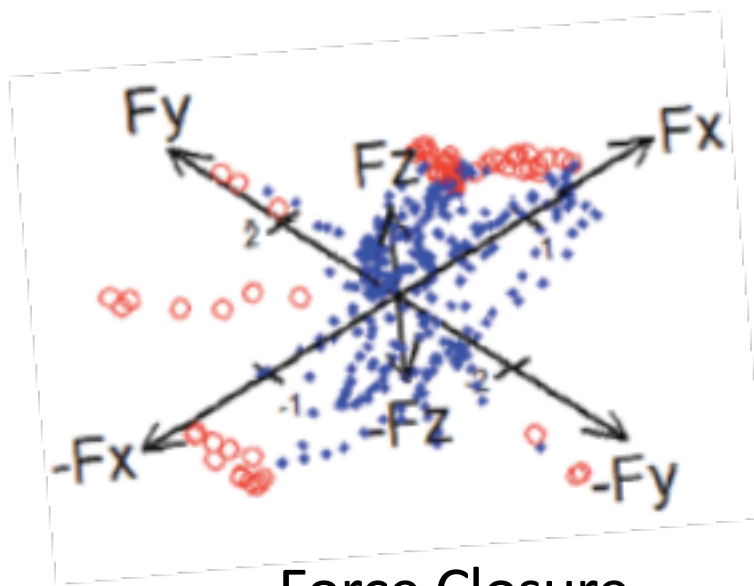
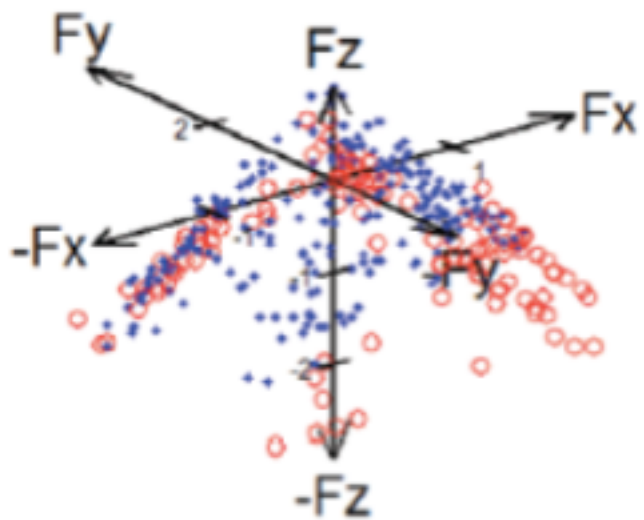
Task 2



Task 3

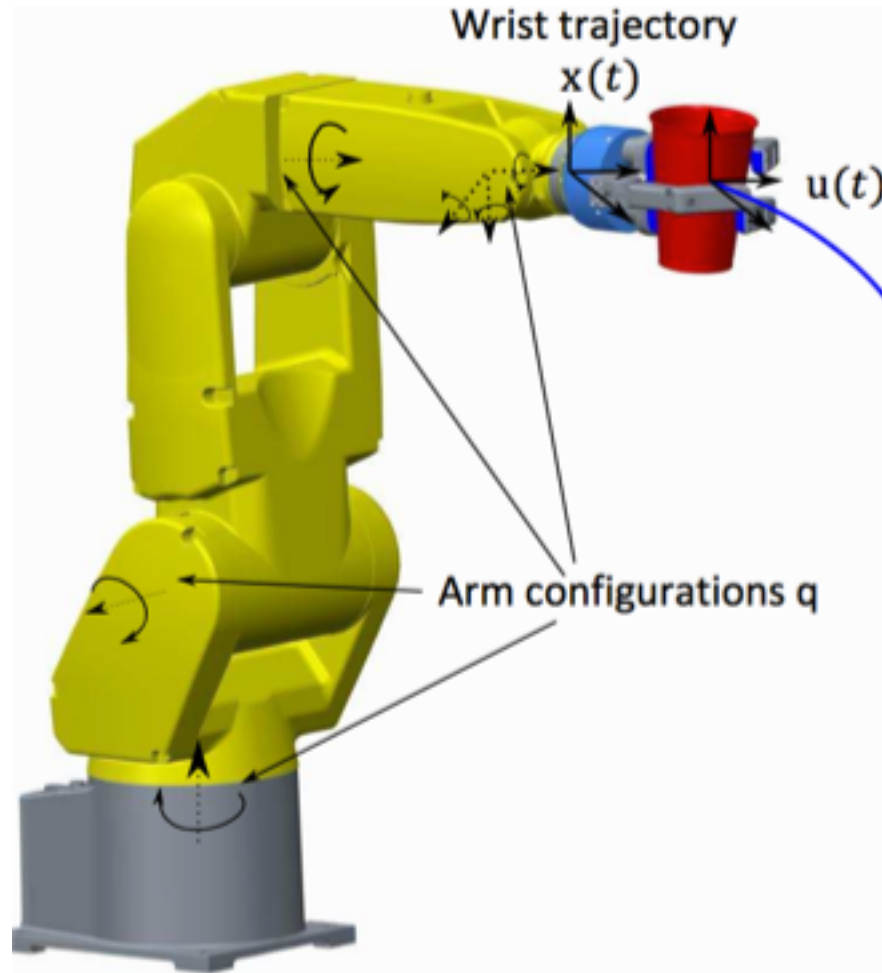


Maximum Task Wrench Coverage



Force Closure

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

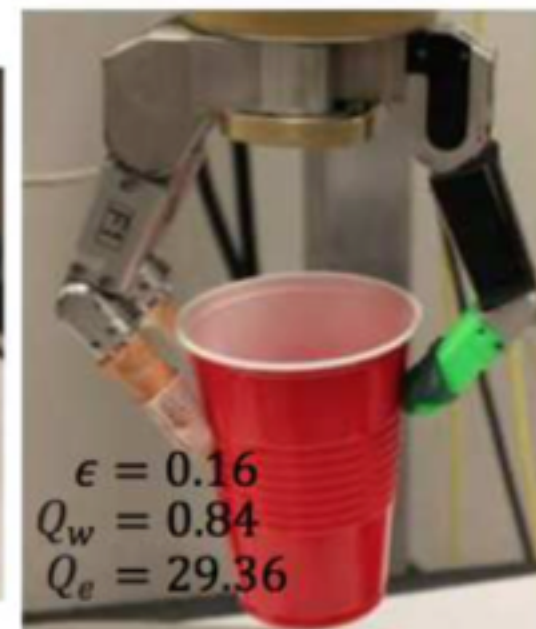
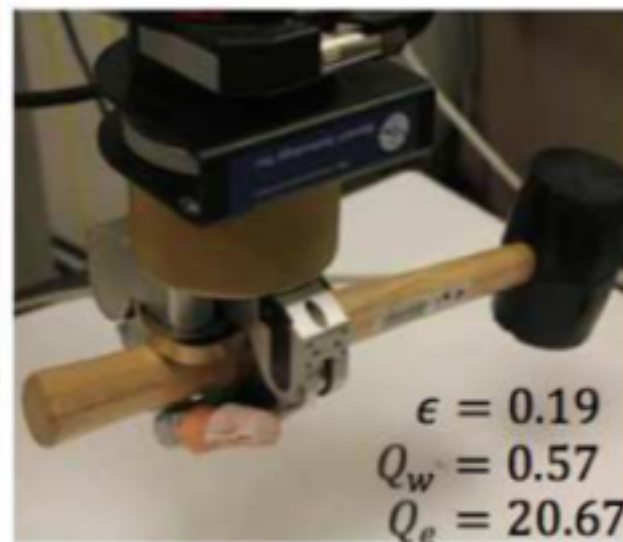
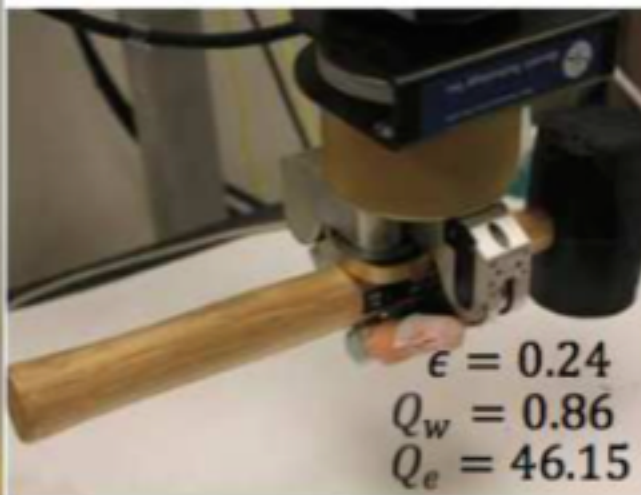
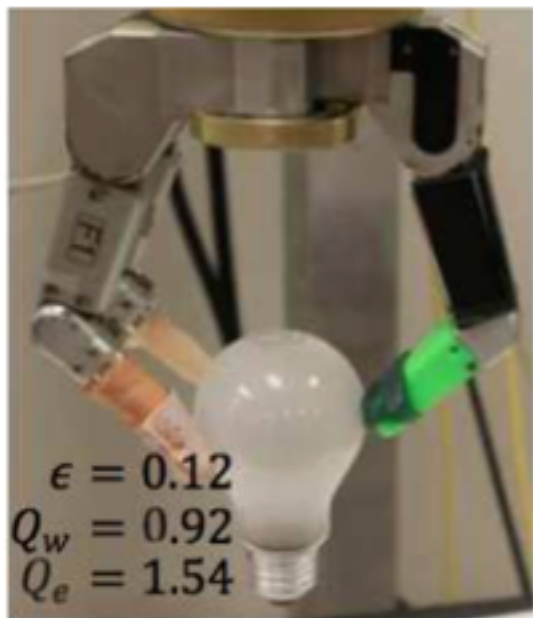
Best Grasp Requests Less Motion

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

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



Support

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Thank You!

Contact: yusun@usf.edu

References:

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- [10] Falco J, Sun Y, Roa M, Robotic Grasping and Manipulation Competition: Competitor Feedback and Lessons Learned. In Robotic Grasping and Manipulation Challenge 2016 (pp. 180-189). Springer, Cham.
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- [12] Lin, Y., and Sun, Y. (2015) Robot Grasp Planning Based on Demonstrated Grasp Strategies, Intl. Journal of Robotics Research, 34(1): 26-42.
- [13] Huang, Y. and Sun, Y. (2015) Generating Manipulation Trajectories Using Motion Harmonics, IROS, 4949-4954.
- [14] Lin, Y. and Sun, Y. (2015) Task-Based Grasp Quality Measures for Grasp Synthesis, IROS, 485-490.
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