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NRI: FND: Scalable Multimodal Tactile Sensing for Robotic Manipulators in Manufacturing

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Tactile sensing

We want:

- **rich** contact data
- coverage of **curved** surfaces
- easy to **integrate** and use!

Joint work with John Kymissis CLUE lab (Columbia EE)

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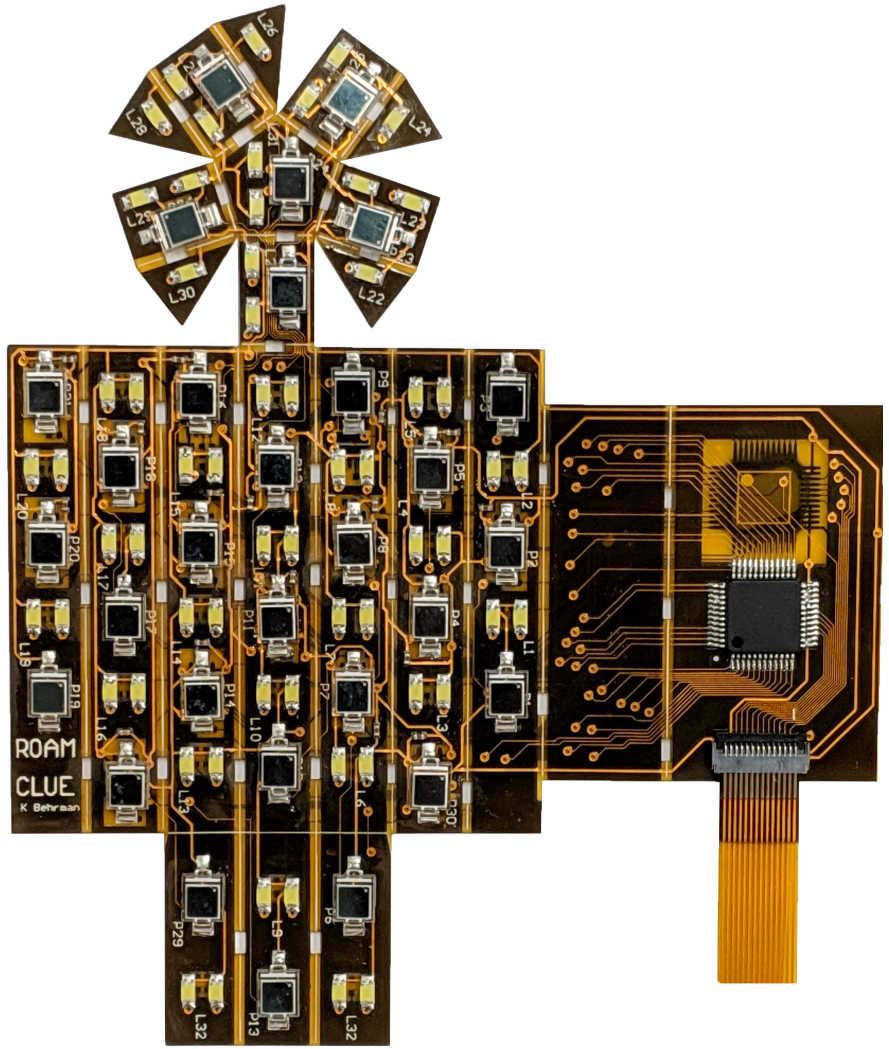
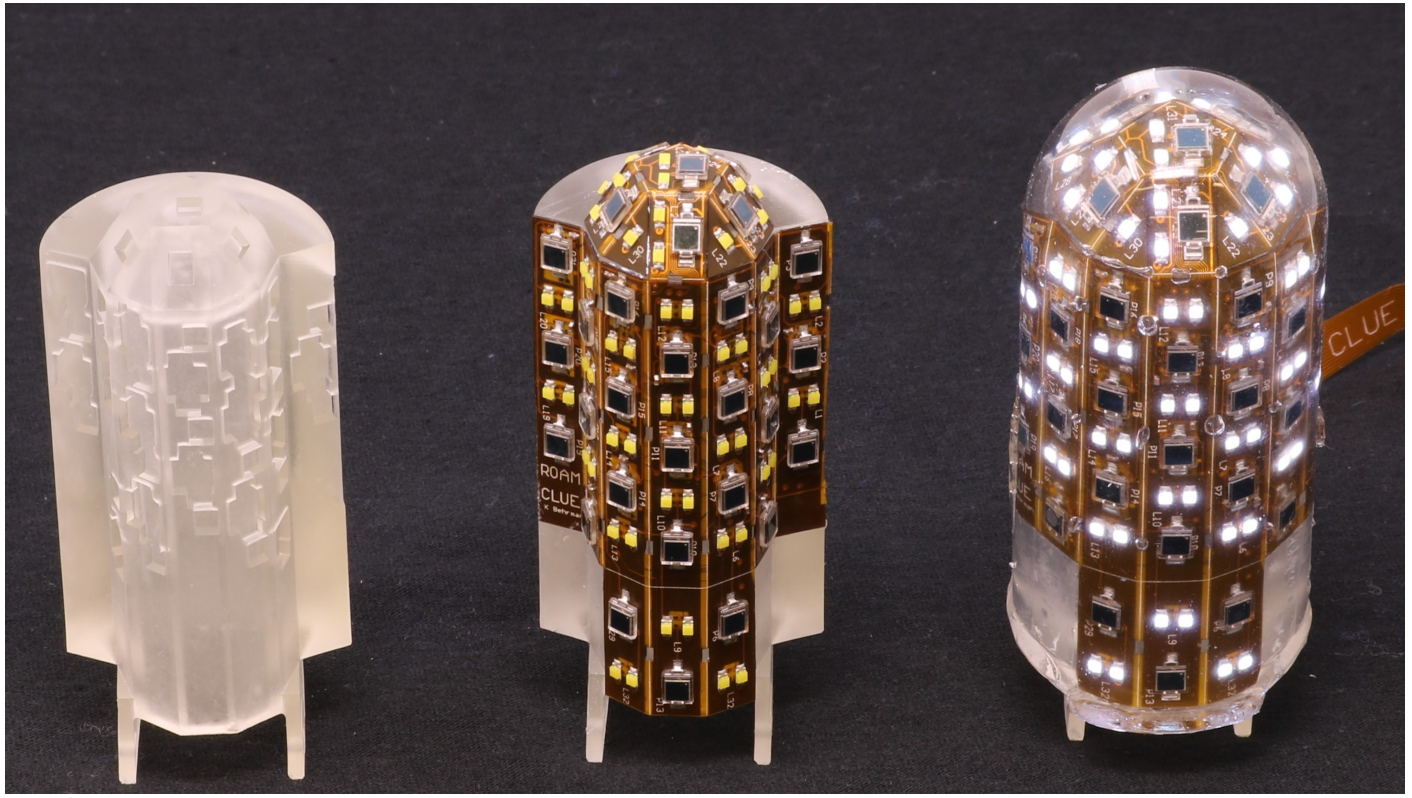
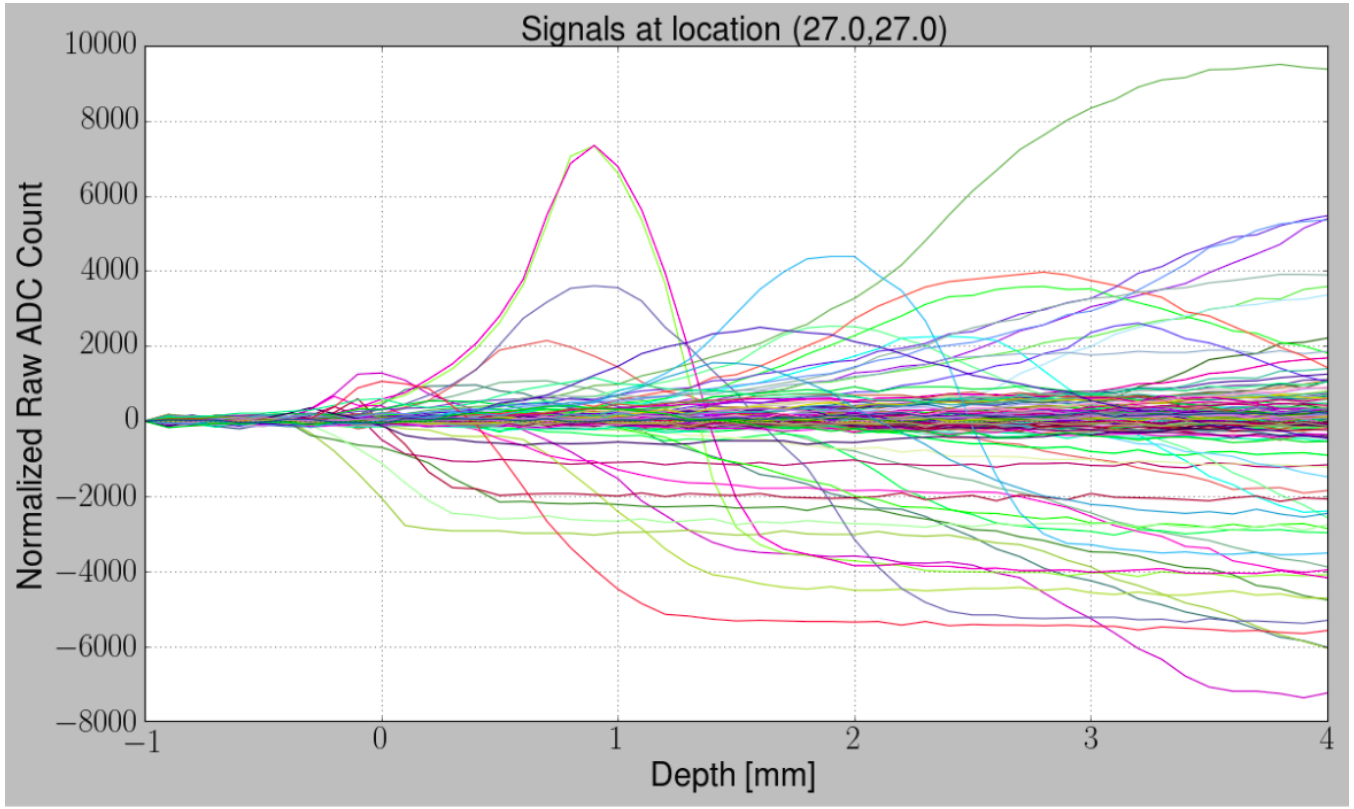


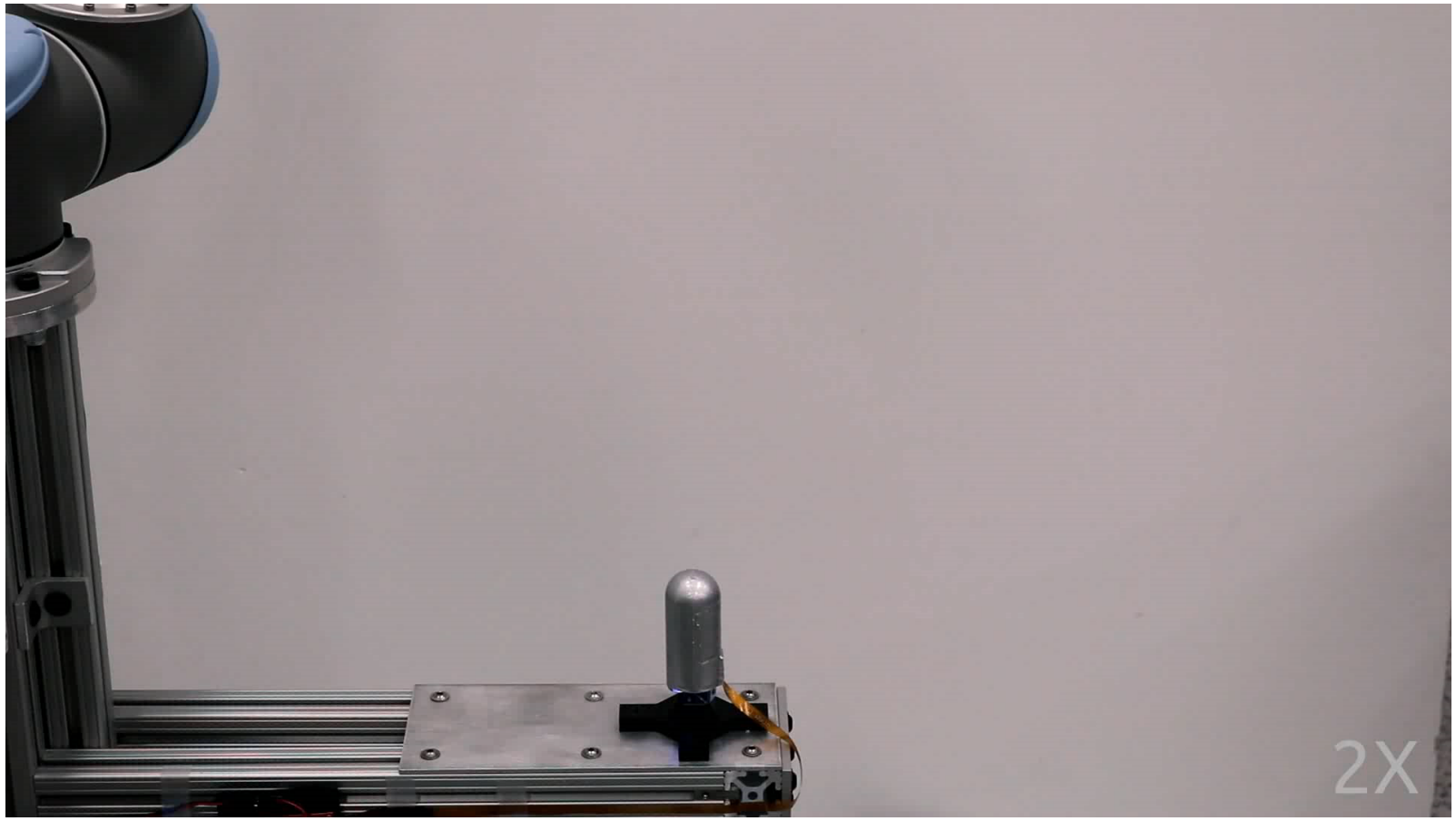


- Hemispherical tip: fully sensed
- Cylindrical body: 190 degrees are sensed
- 32 diodes, 32 LED pairs, multiplexed: **1,024 signals**

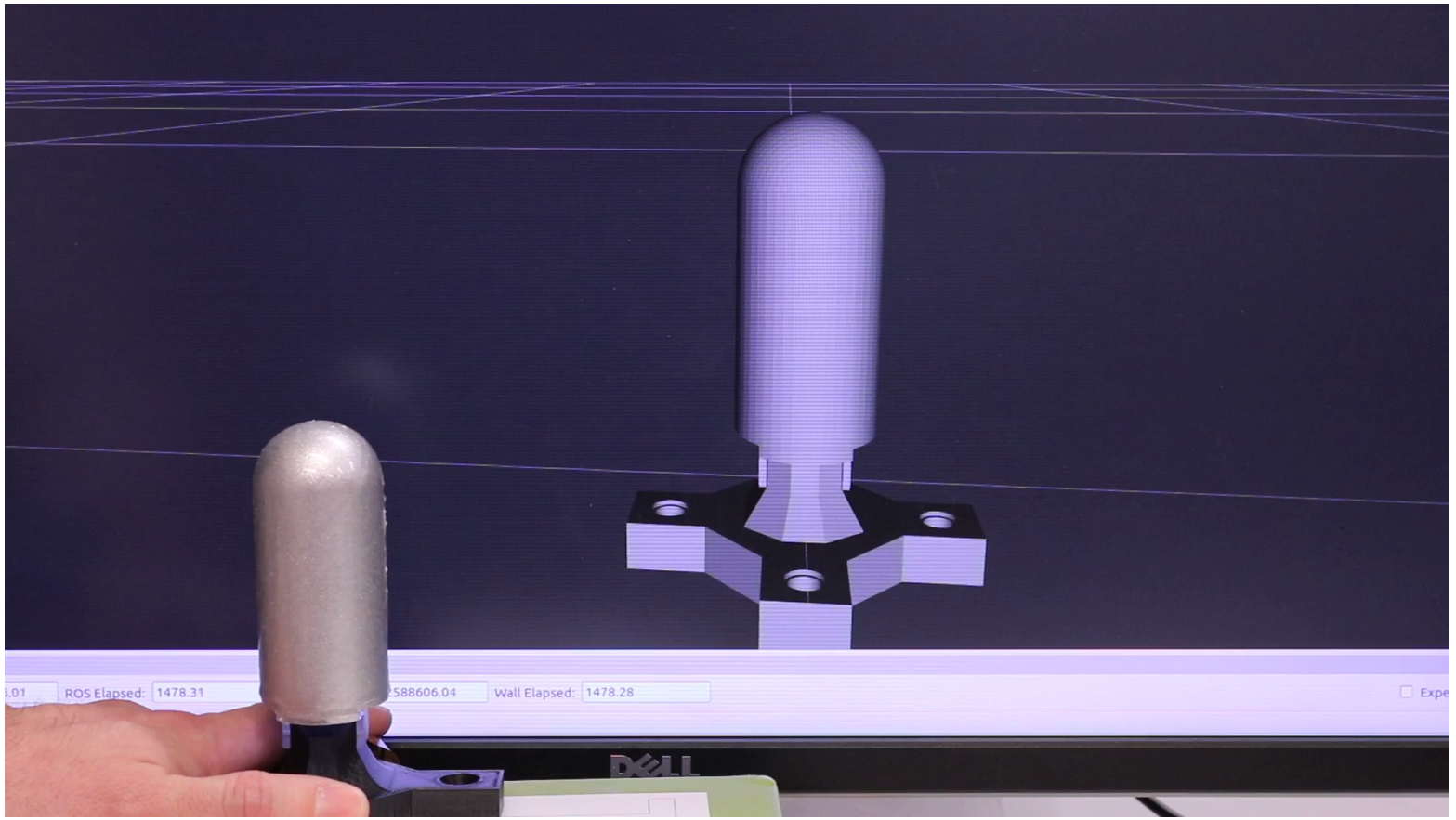
A Tactile Sensor for Machine Learning



Training Data Collection



Touch Localization



[Piacenza et al., T-MECH 2020]

New dexterous hands

Next steps: manipulation

- With trained tactile sensors providing touch location and normal force
- End-to-end learning, based on raw tactile signals

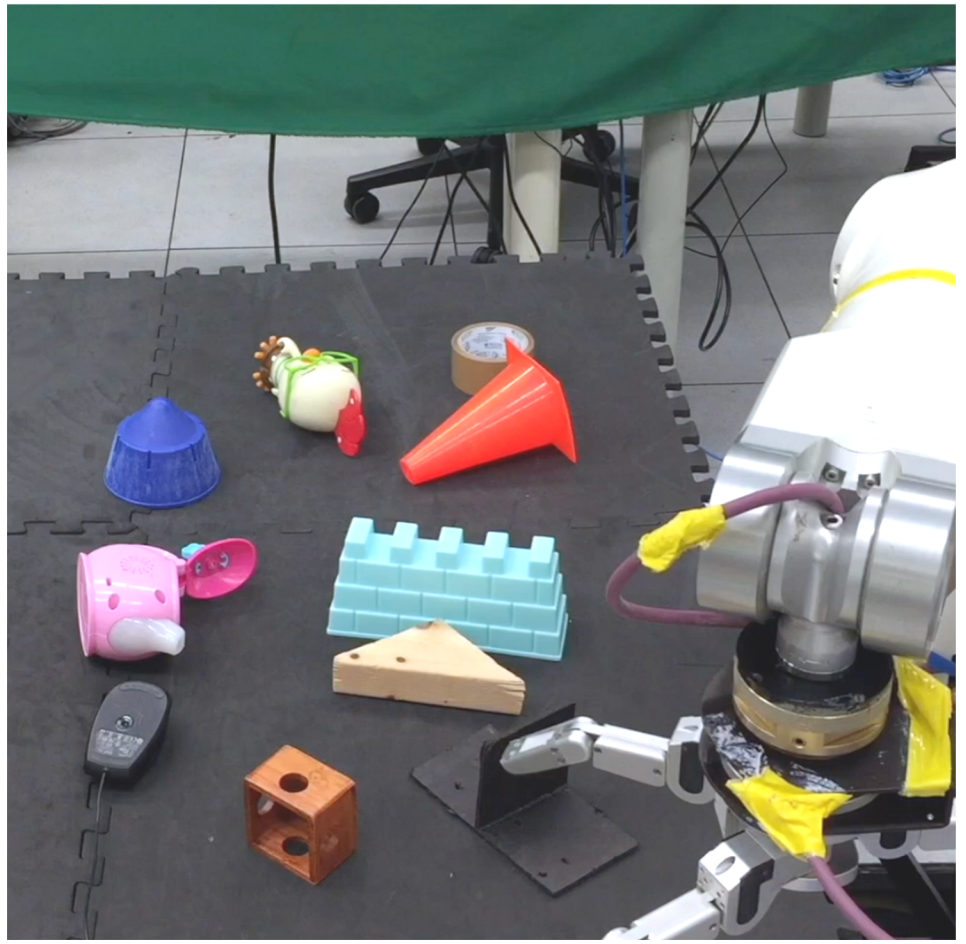
3 fingers, 8 DOF
Tactile sensors (proximal and distal)
Torque sensing at every joint

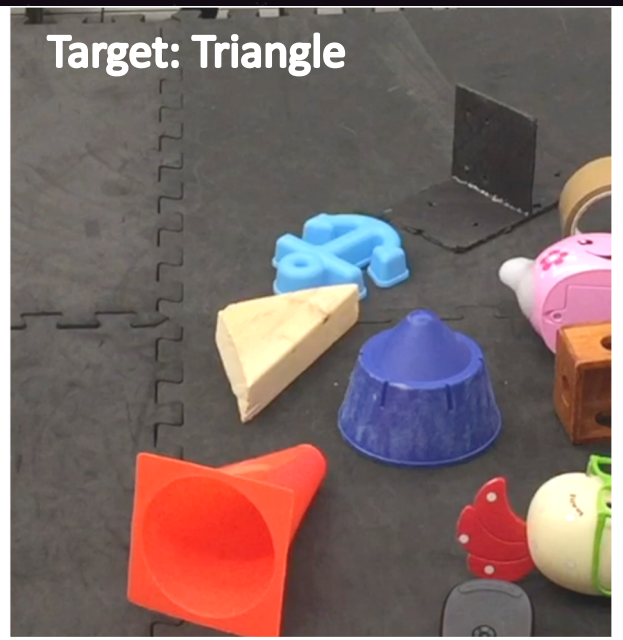
4 fingers, 12 DOF
Tactile sensors (distal only)
No torque sensing

MAT: Multi-Fingered Adaptive Tactile Grasping via Deep Reinforcement Learning

Key Takeaways:

1. Closed-loop grasping using tactile only
2. Addresses the visual occlusion problem
3. Robust under calibration error
4. Works with cluttered unseen objects
5. Multi-fingered hands with full-DOF poses
6. Powerful add-on to vision grasping systems
7. Direct tactile sim-to-real transfer





Method

Cluttered unseen objects **with tactile only and no vision**

Lift Arm

Close Finger 3 by small delta?

Close Finger 2 by small delta?

Close Finger 1 by small delta?

Lift?

Yes

No

Reopen All Fingers?

Yes

Reopen All Fingers

No

Adjust End-Effector Position and Orientation

Action a_t

Binary Tactile Contacts

Joint Angles

Tactile Contact Locations

Collect Observations

Tactile Contacts

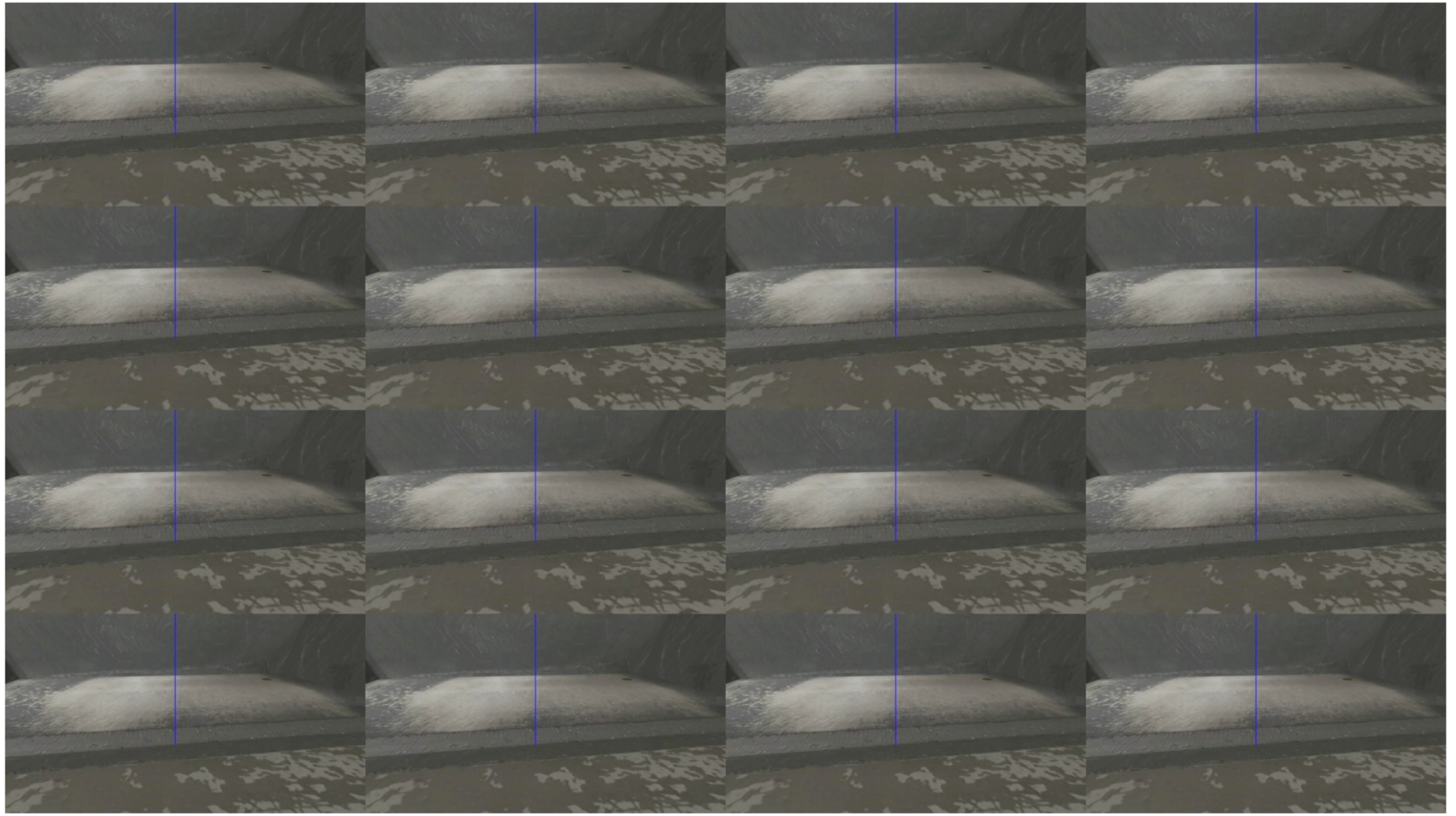
Training

8 hours of simulation training

300+ random objects

1000+ random cluttered scenes

No GPU needed, only using tactile input, no vision

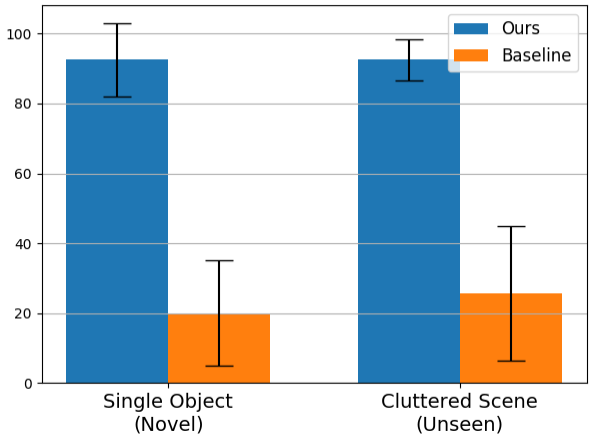


Experimental Results under Grasp Perturbation / Calibration Error

Blue: MAT

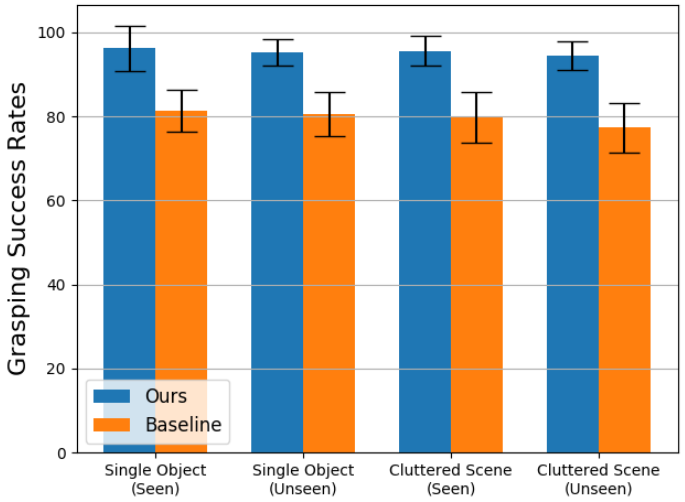
Orange: Vision-based Baseline

Real-World



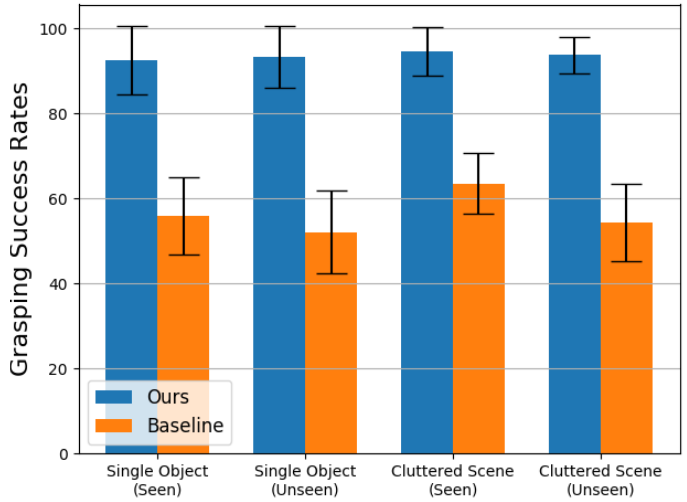
Simulation

15% Better under 1cm Error



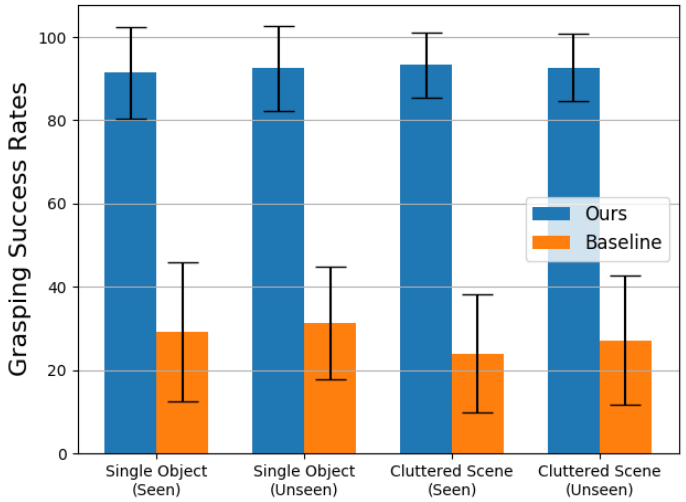
1cm

35% Better



2.5cm

65% Better



5cm

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Main References:

P. Piacenza, K. Behrman, B. Schifferer, I. Kymissis and M. Ciocarlie. "A Sensorized Multicurved Robot Finger with Data-driven Touch Sensing via Overlapping Light Signals", IEEE Transactions on Mechatronics, in press. Available at: https://roam.me.columbia.edu/publications

B. Wu, I. Akinola, J. Varley, and P. K. Allen, “MAT: Multi-fingered adaptive tactile grasping via deep reinforcement learning,” in Conference on Robot Learning (CoRL), 2019.
Website: http://crlab.cs.columbia.edu/MAT/