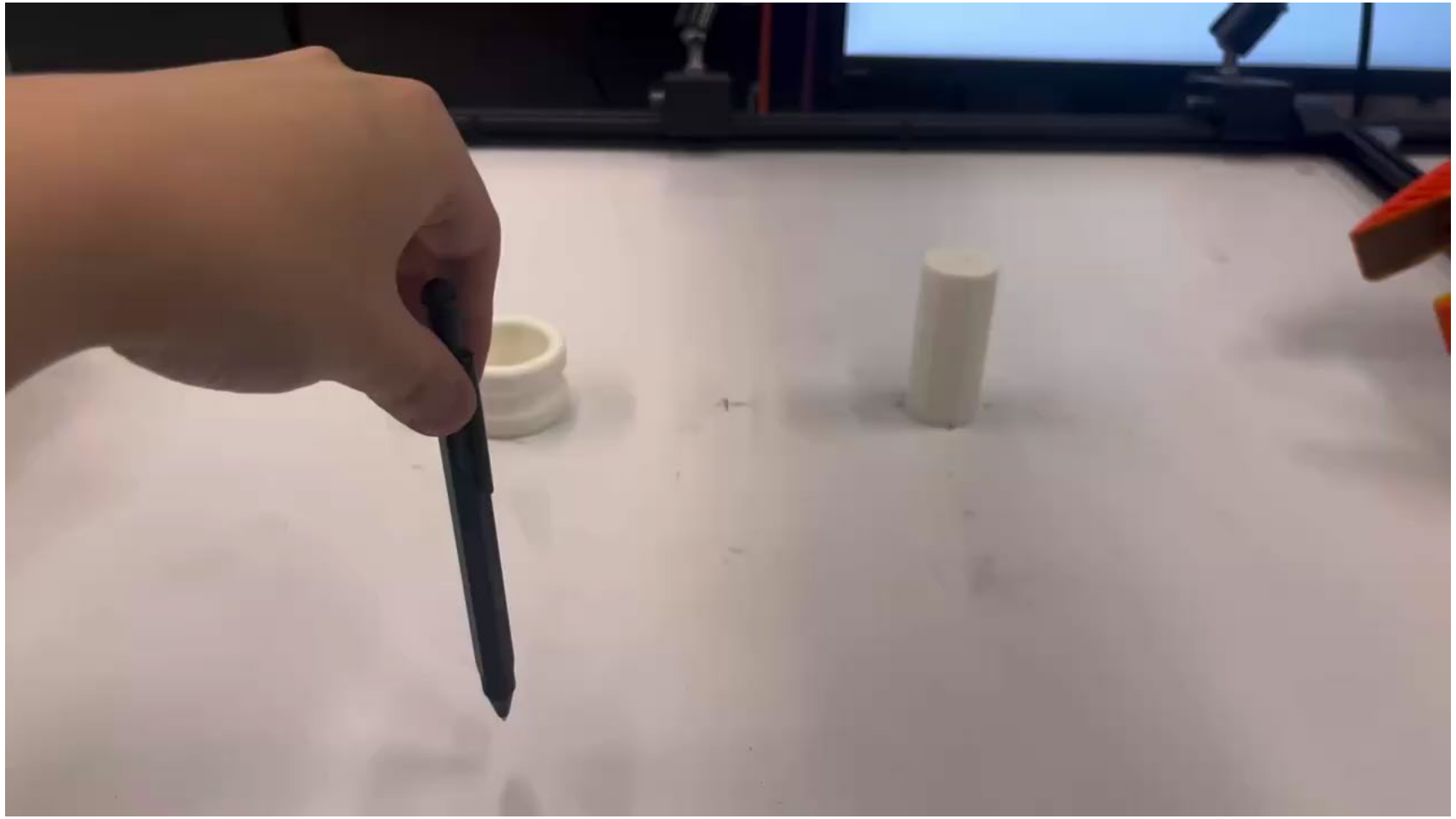
What I Wish I Had for Visual-Tactile Sensing?

Binghao Huang
@ Columbia

I want to play a Game

Test your Dexterity!



Cheers!

You just learned
a Dexterous Skill
and
Notice your
Flexible Tactile Sensor

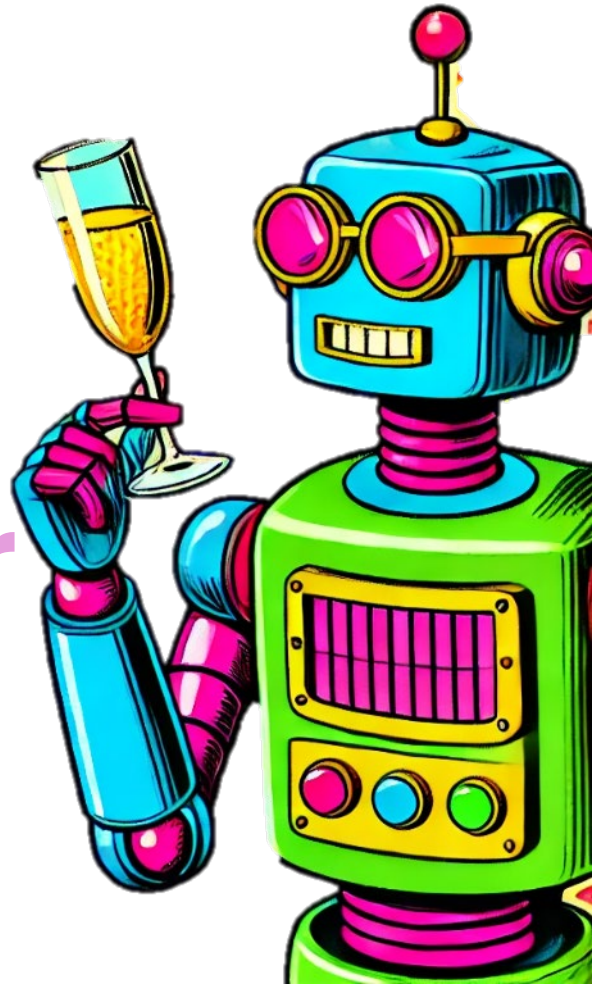
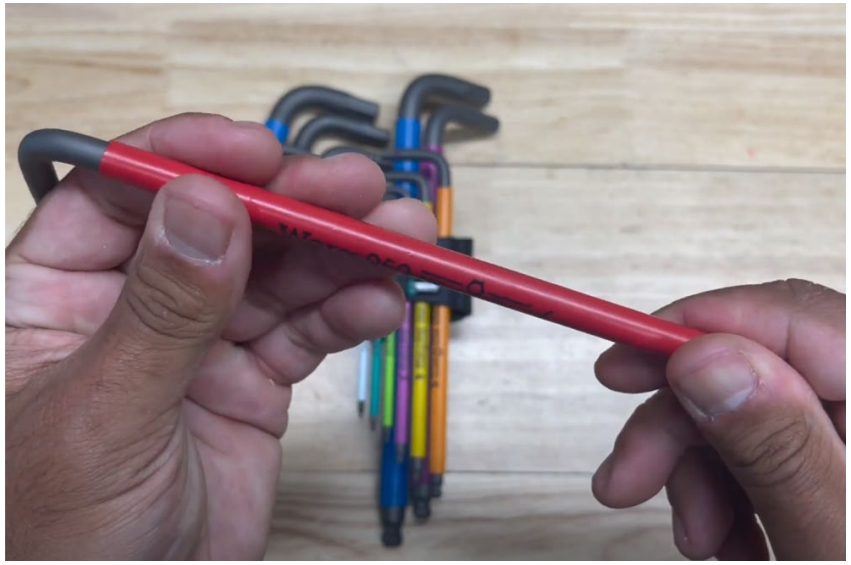


Figure design credits Rao Fu

How humans combine Vision and Touch?

Fragile Objects Manipulation



Bimanual In-Hand Reorientation

How humans combine Vision and Touch?

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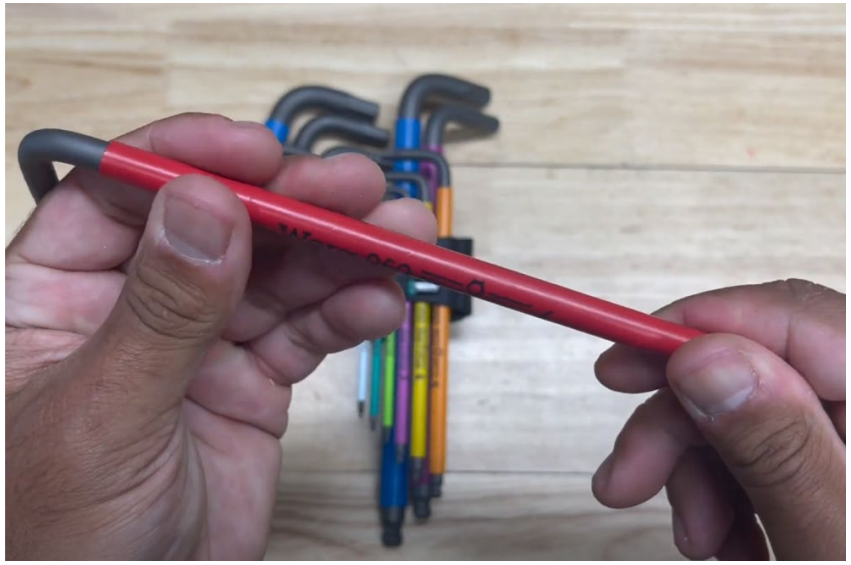

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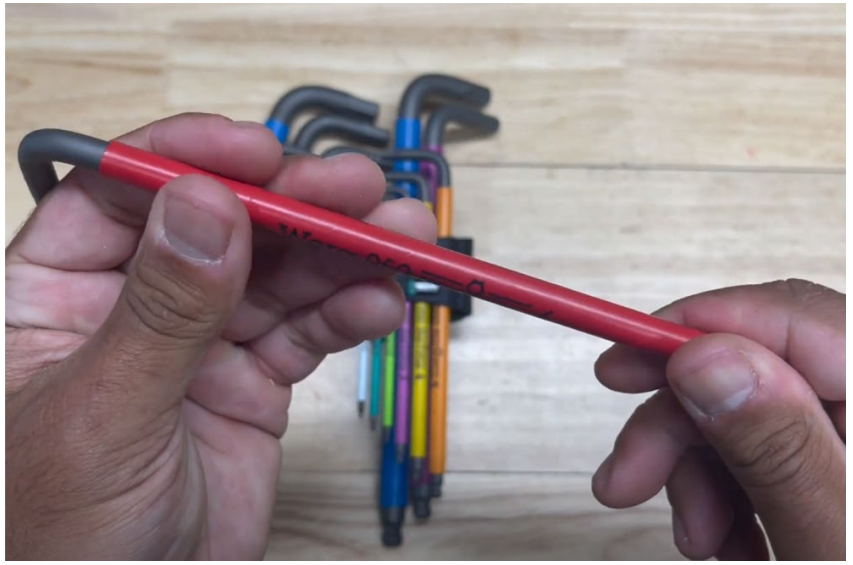


Bimanual In-Hand Reorientation

Action

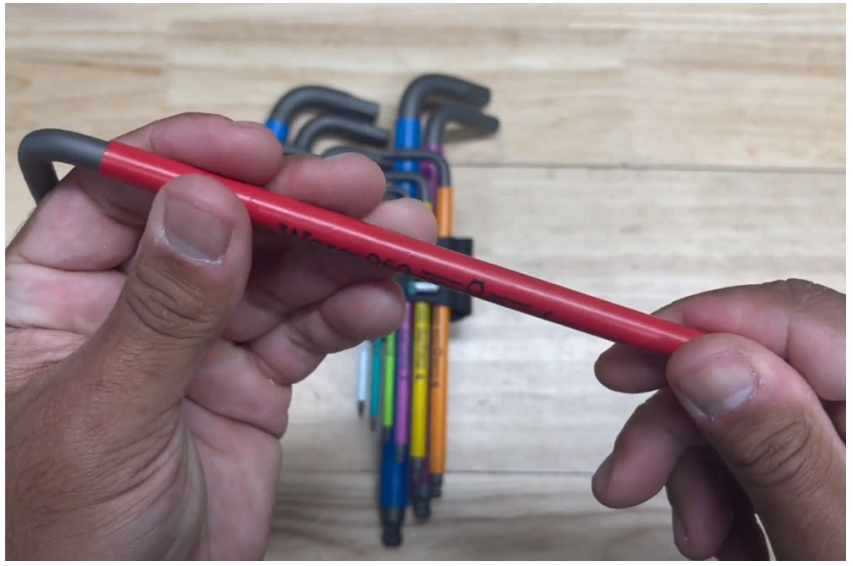
Pose Geometry

Force Friction

Task-relevant information

How humans combine Vision and Touch?

Fragile Objects Manipulation



Bimanual In-Hand Reorientation

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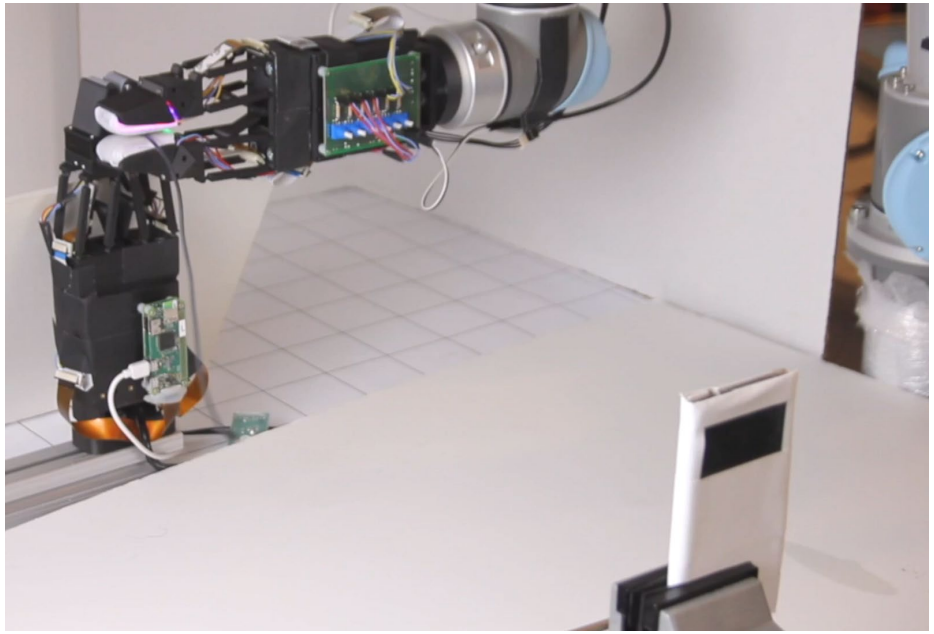
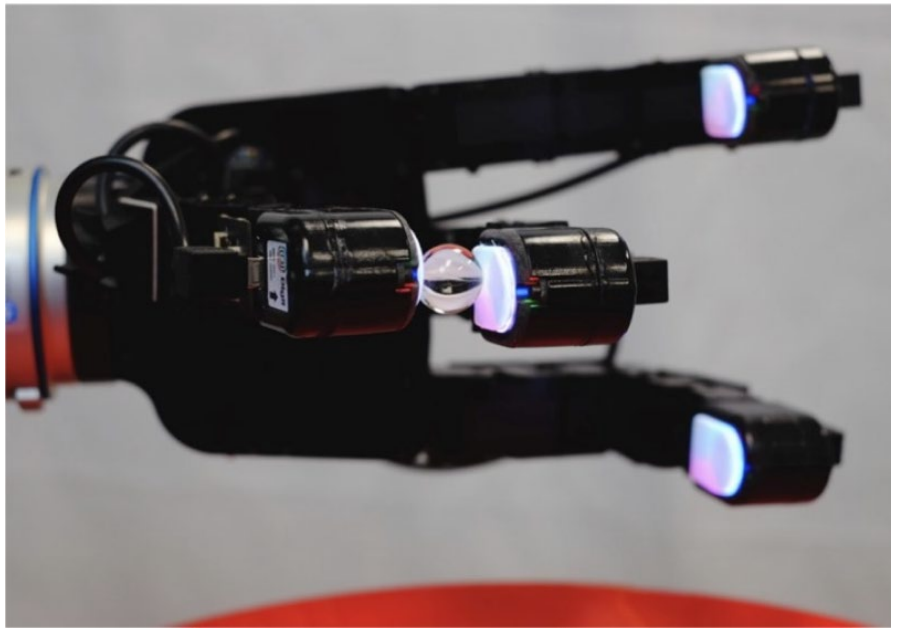
Pose Geometry

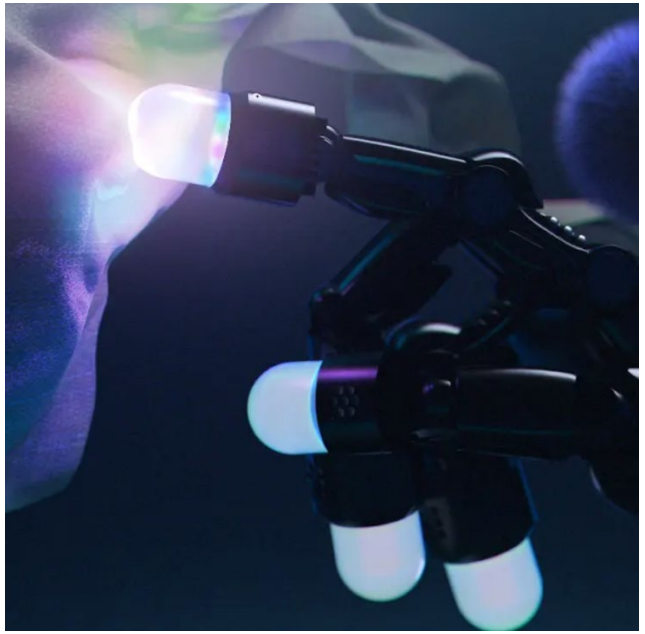
Force Friction

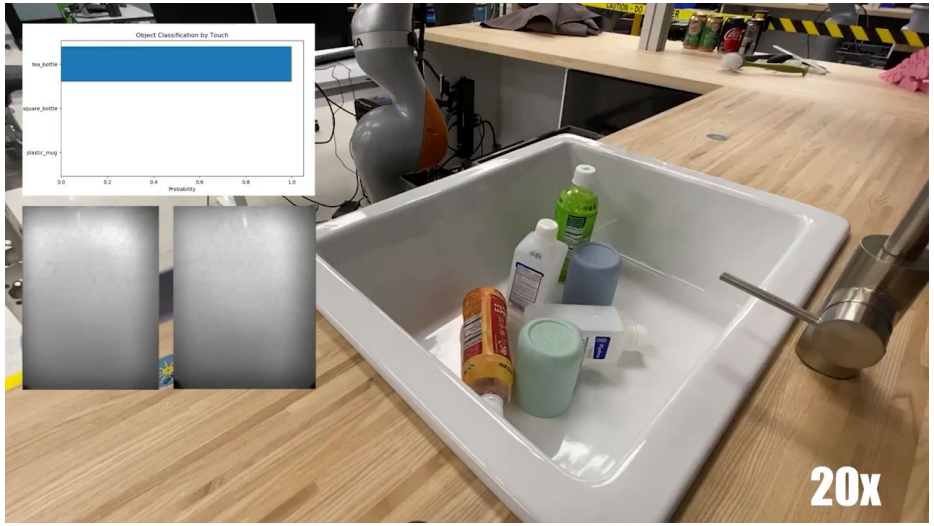
Task-relevant information

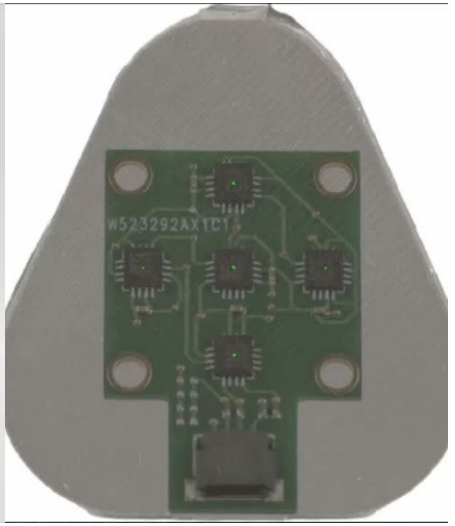
Can we enable robots with those abilities?

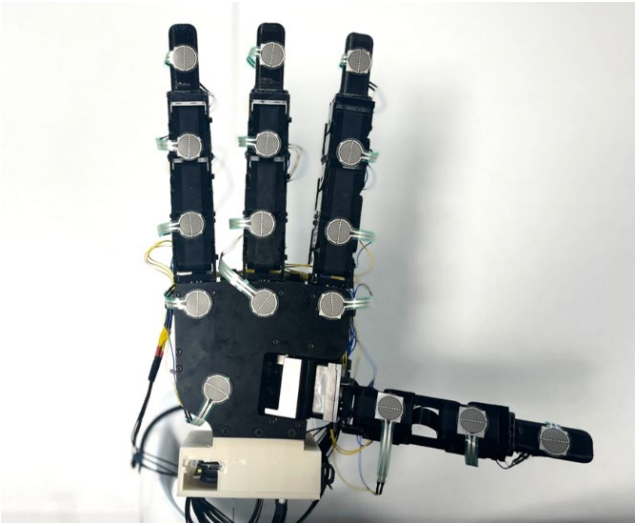






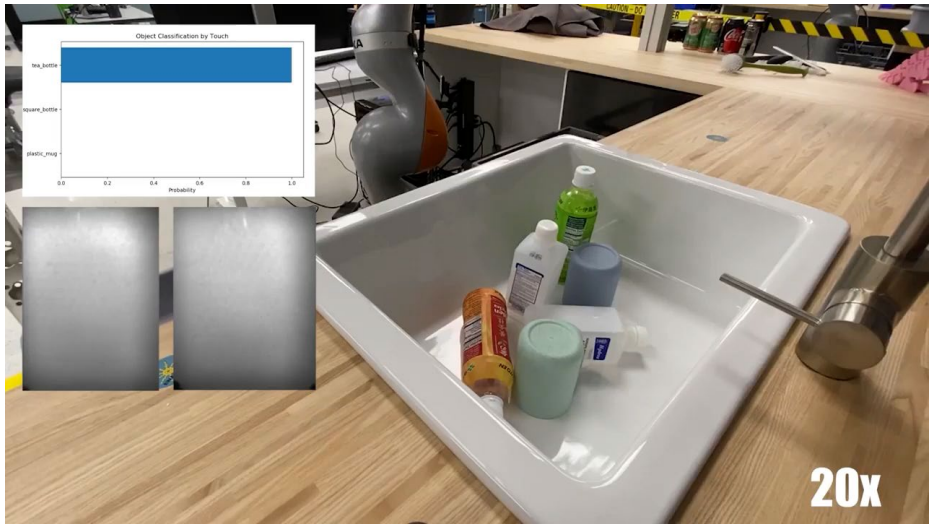


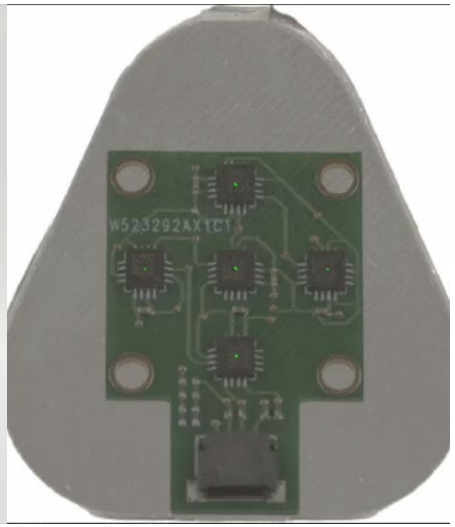


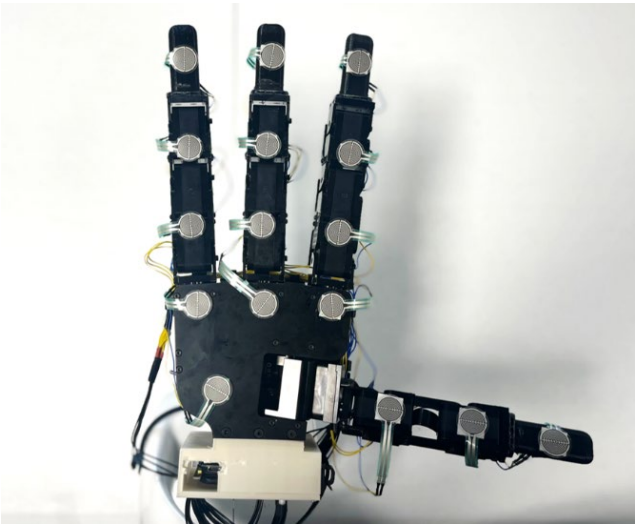


A lack of commonly accepted, scalable solutions in the Robotics field...

High Resolution
Shear Force
Bulky
Small Coverage







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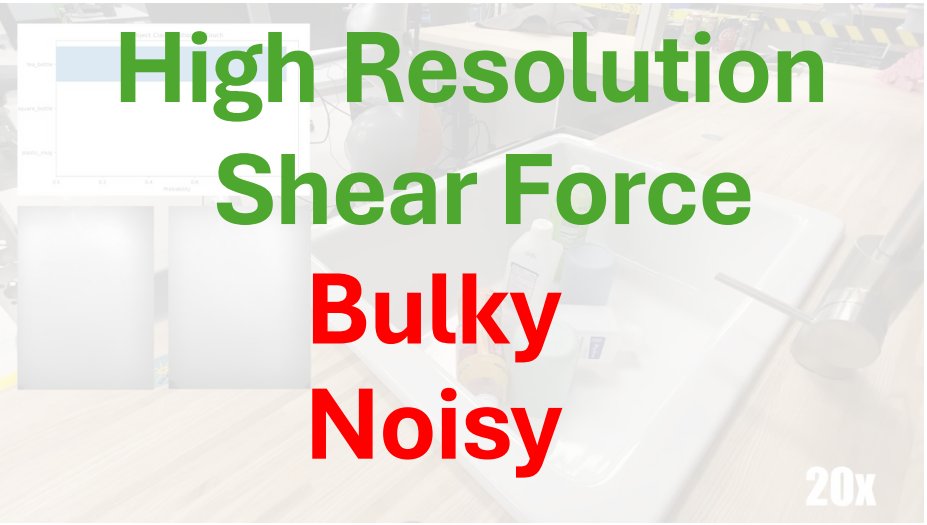

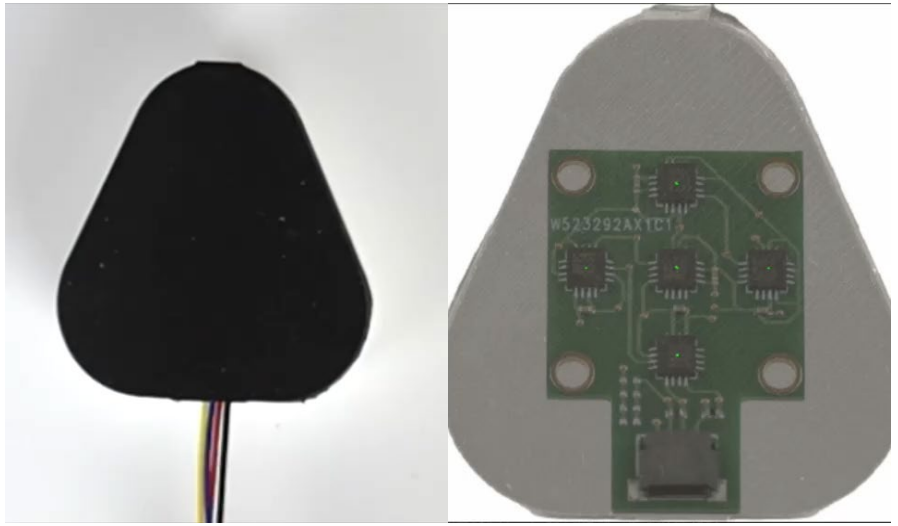

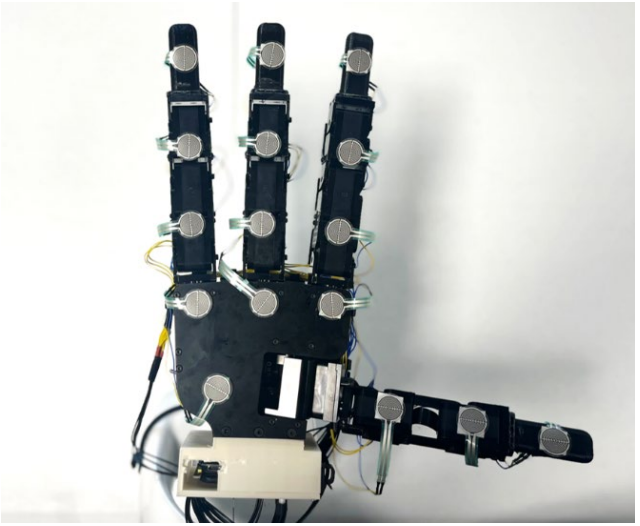

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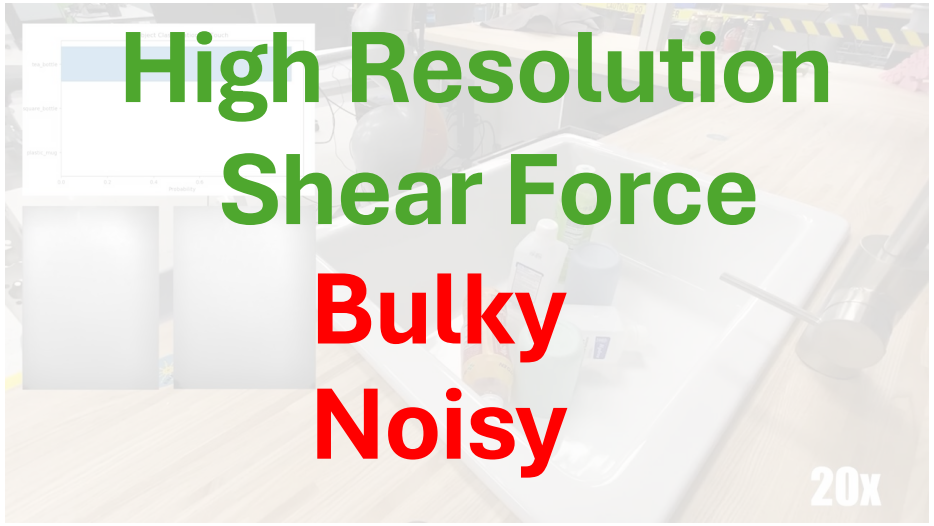
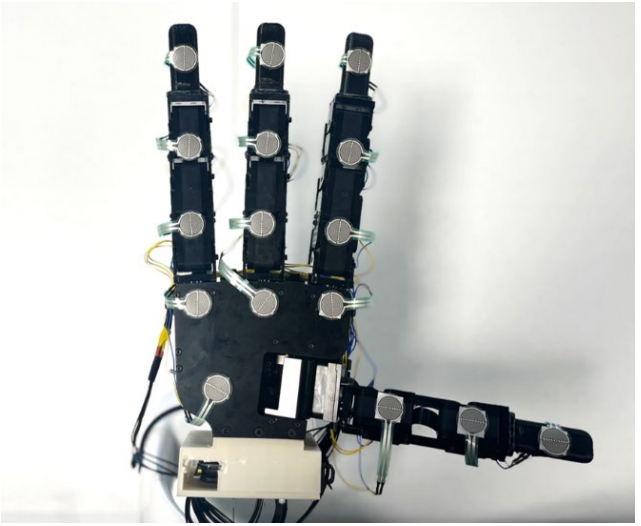


High Resolution
Shear Force
Bulky
Noisy

Shear Force
Low Resolution
Noisy



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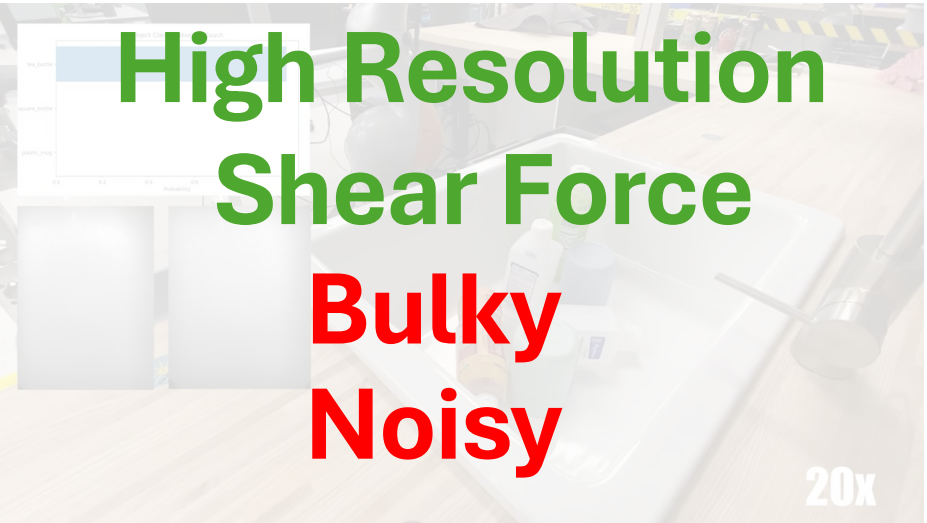

A lack of commonly accepted, scalable solutions in the Robotics field...

A Well-Designed Tactile is Needed for Robot Learning

Hardware

Scalable
High Resolution
Flexible

Learning

Multimodal Perception
System Design
representation

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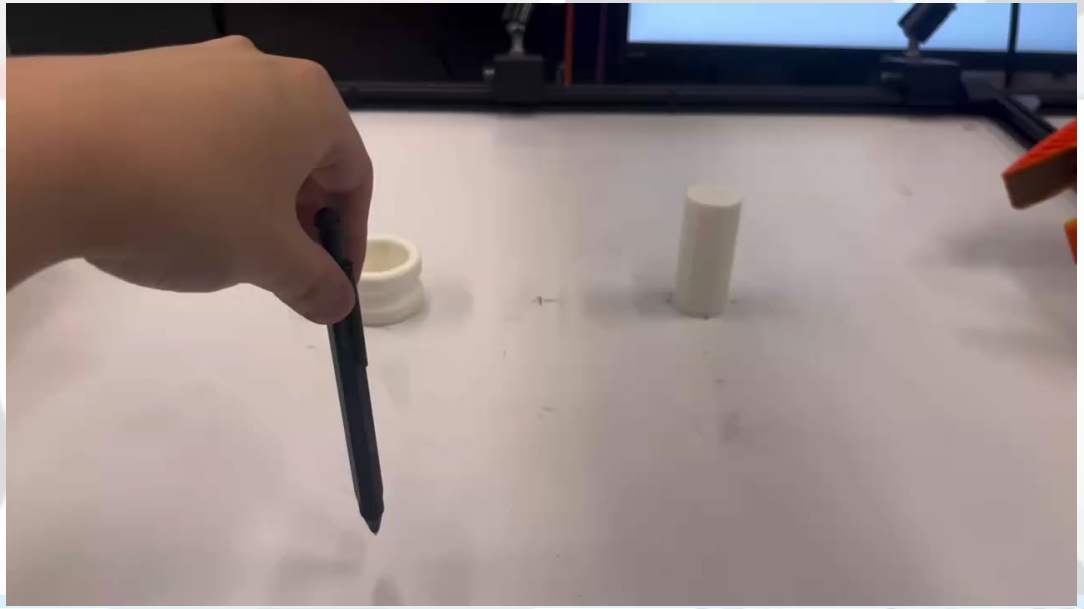

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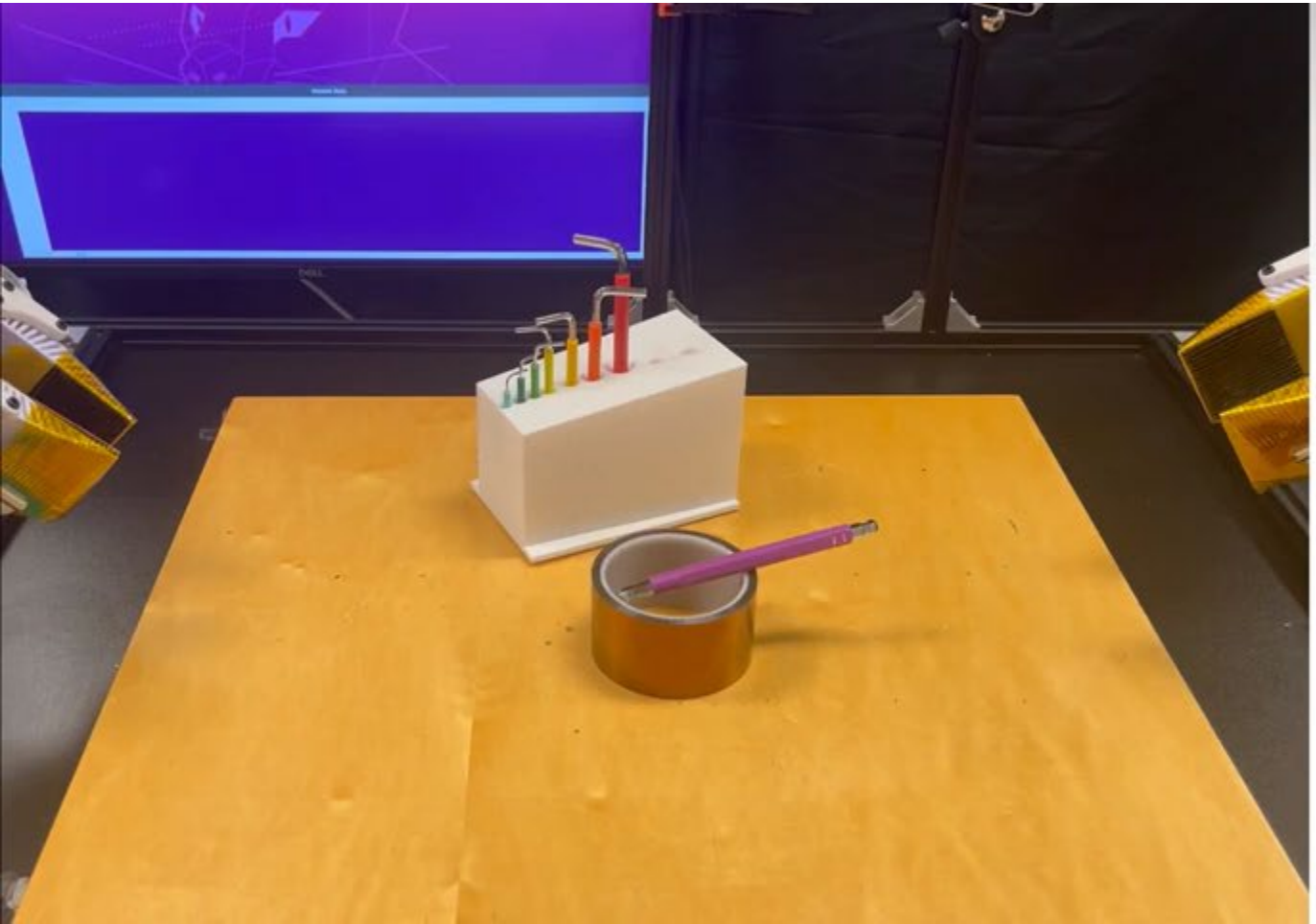
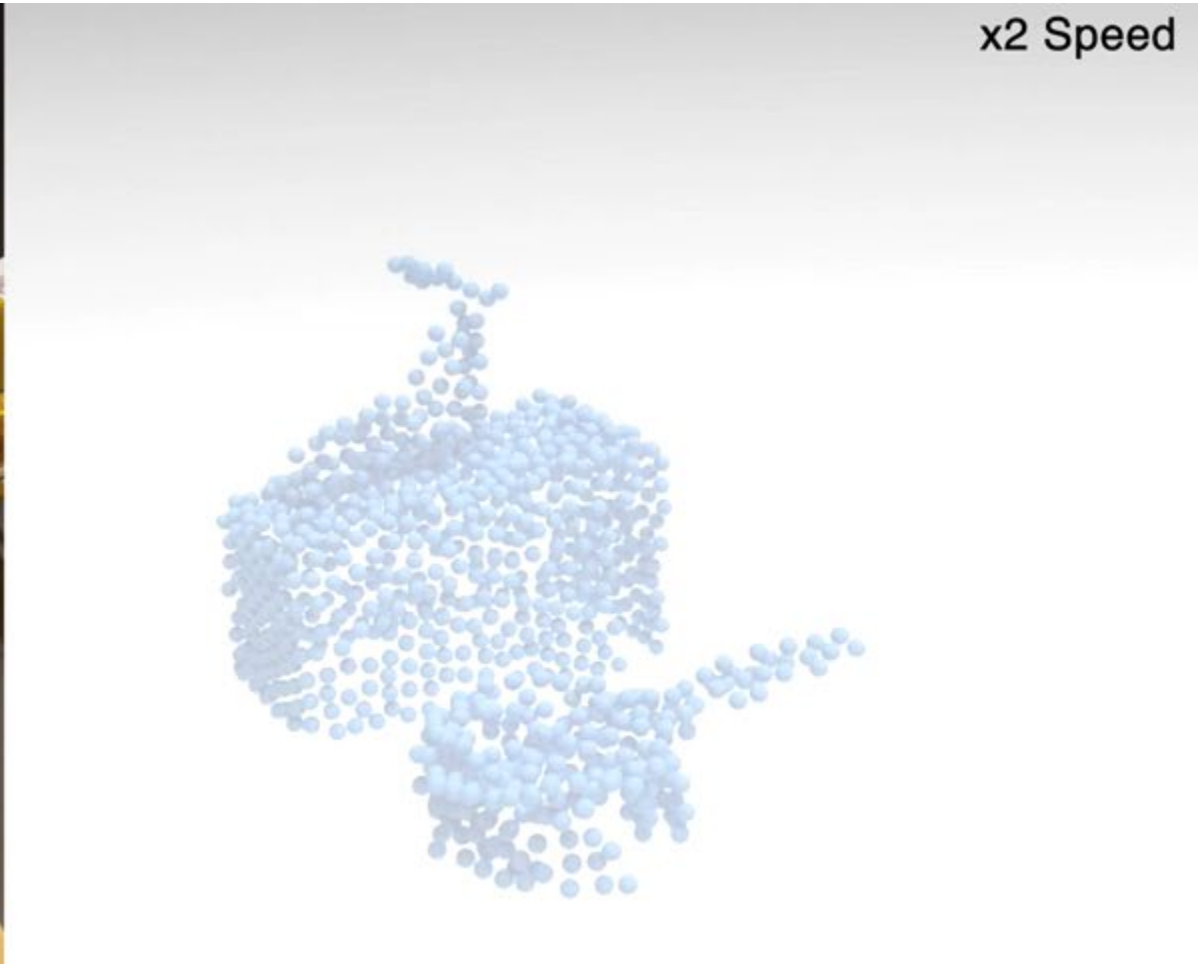
3D-ViTac:

Learning Fine-Grained Manipulation with Visuo-Tactile Sensing

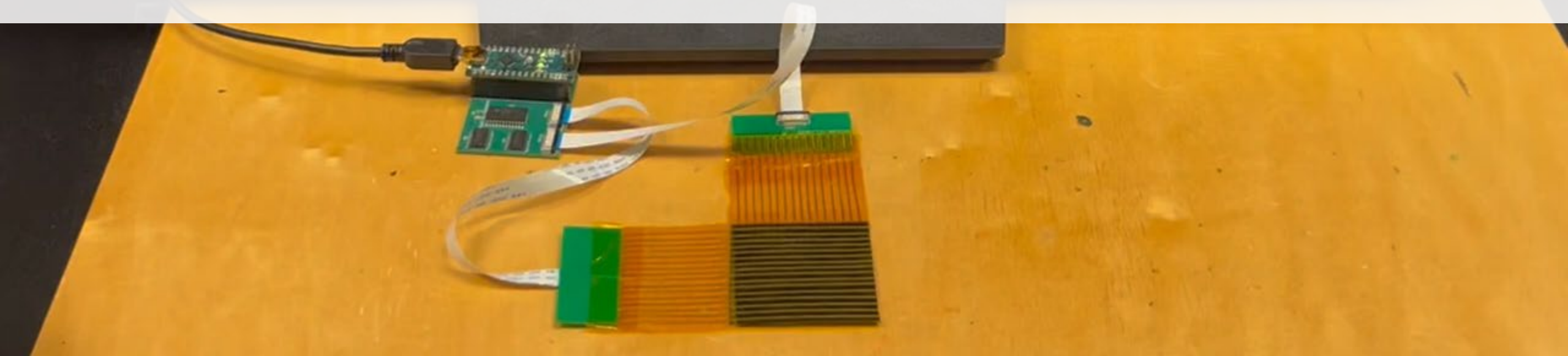
Binghao Huang[1], Yixuan Wang[1], Xinyi Yang[2], Yiyue Luo[3], Yunzhu Li[1]

[1]Columbia University, [2]University of Illinois Urbana-Champaign, [3]University of Washington





What is Flexible Tactile Sensor?



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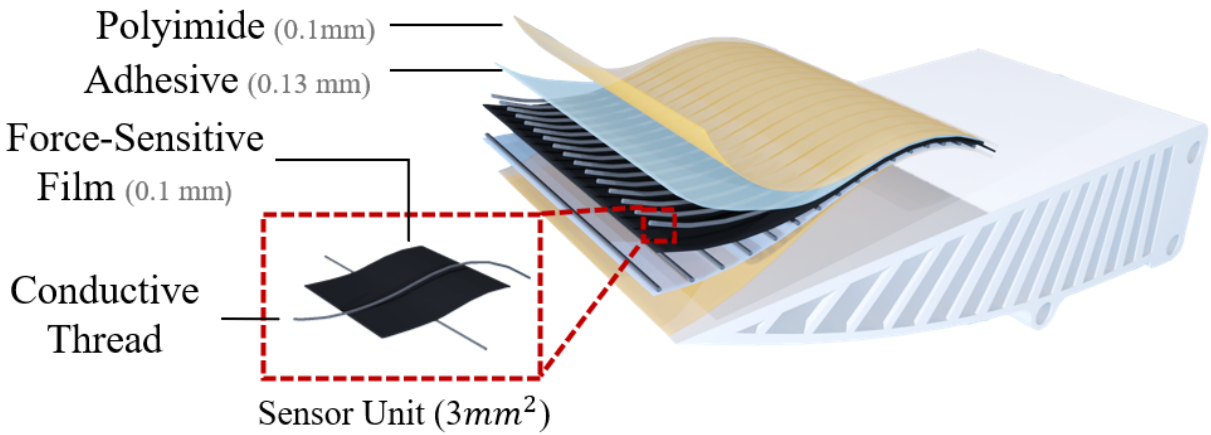
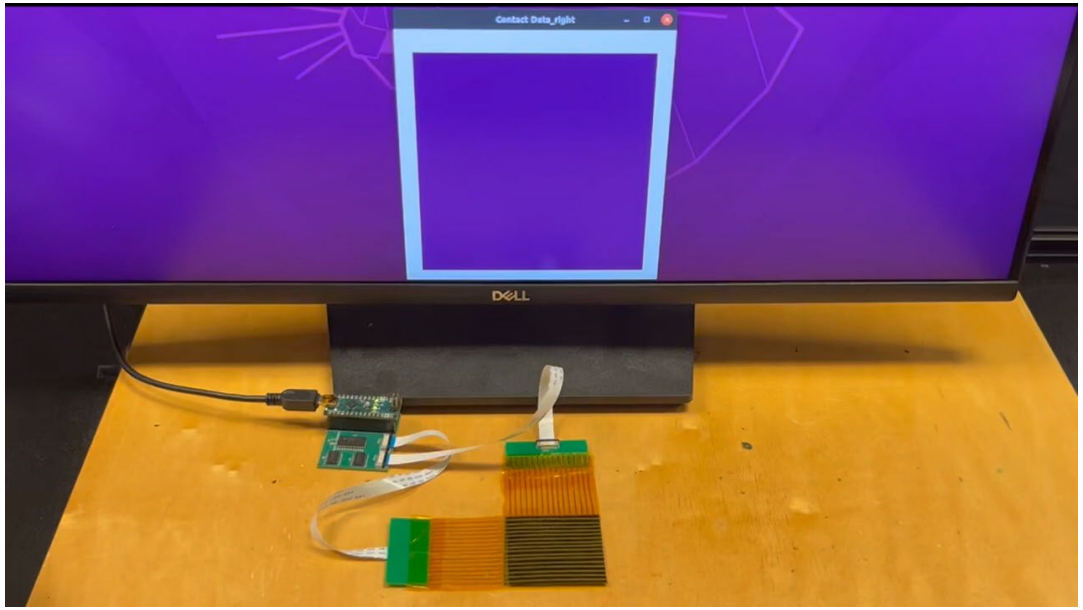


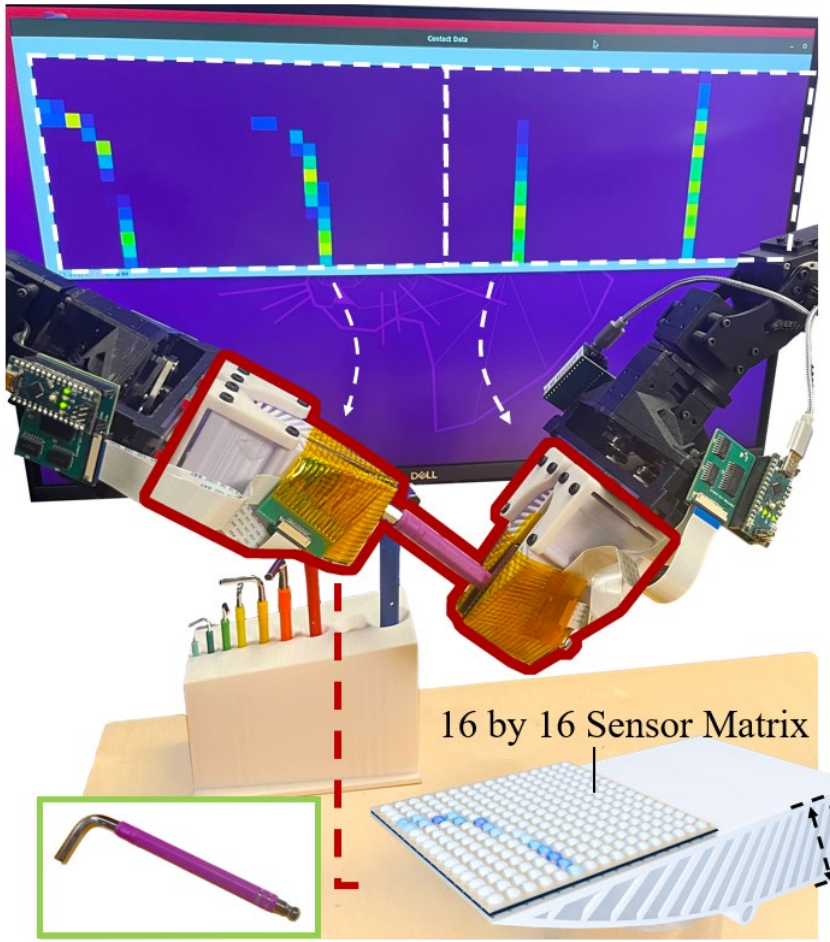
Tactile Principle



Hardware Test

Flexible, Low-cost, Robust!

How We Build Multi-Sensory System?



High Resolution Tactile with Multi-View RGBD Camera

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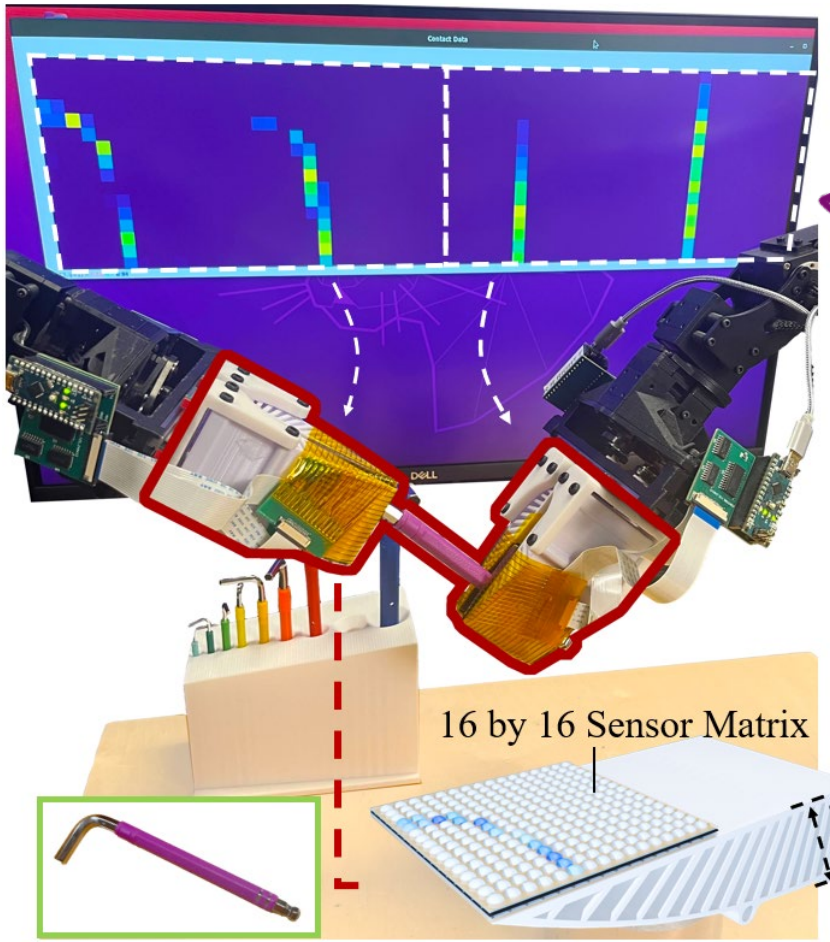

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Visual Haptic Feedback

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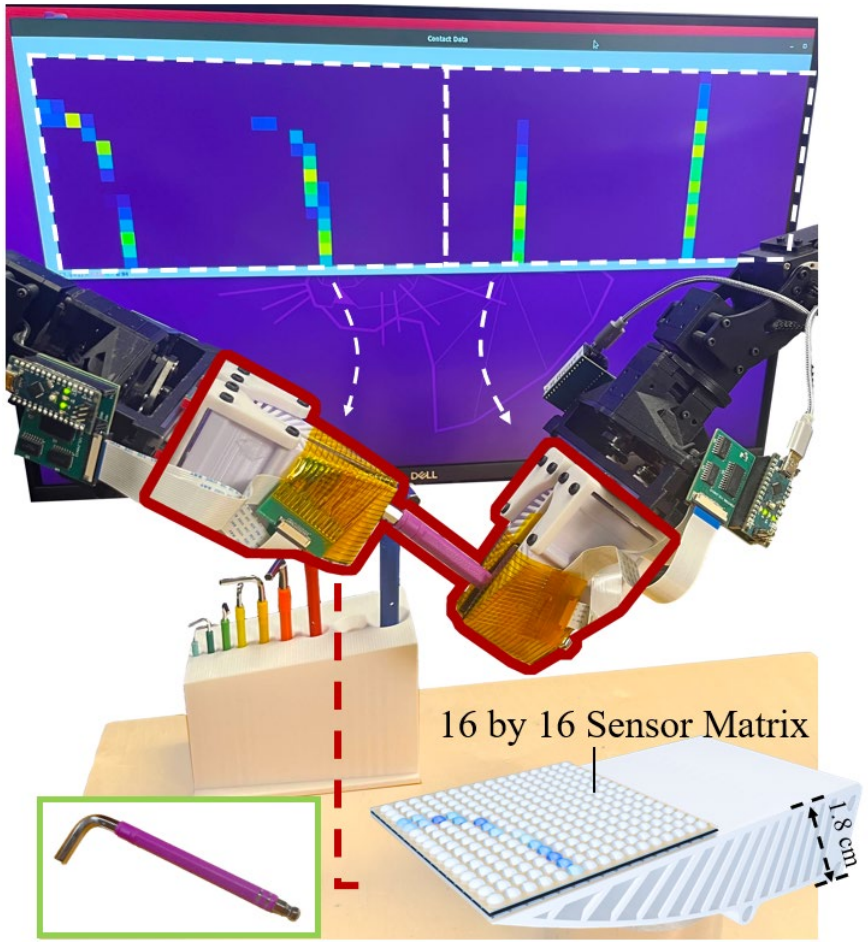
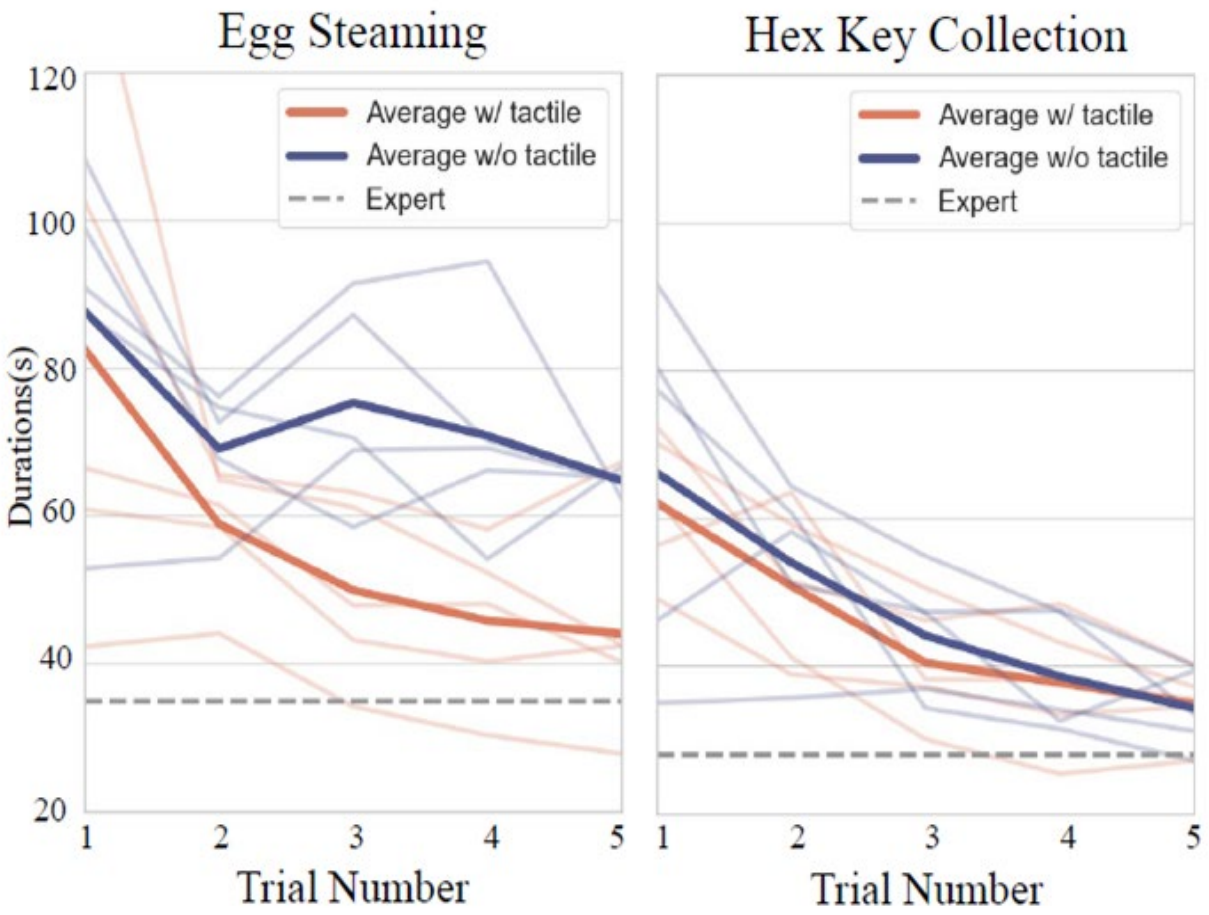
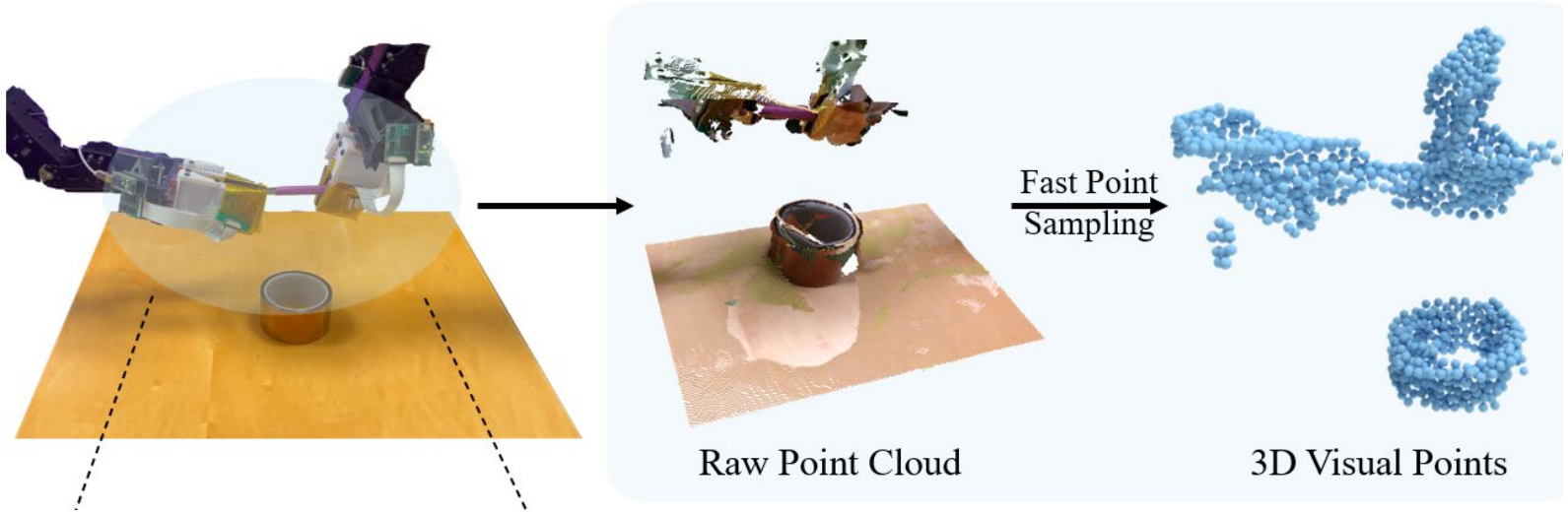


High Resolution **Tactile** with Multi-View RGBD **Camera**



Visual Haptic feedback improve teleoperation data quality

Learning with Visuo-Tactile Policy



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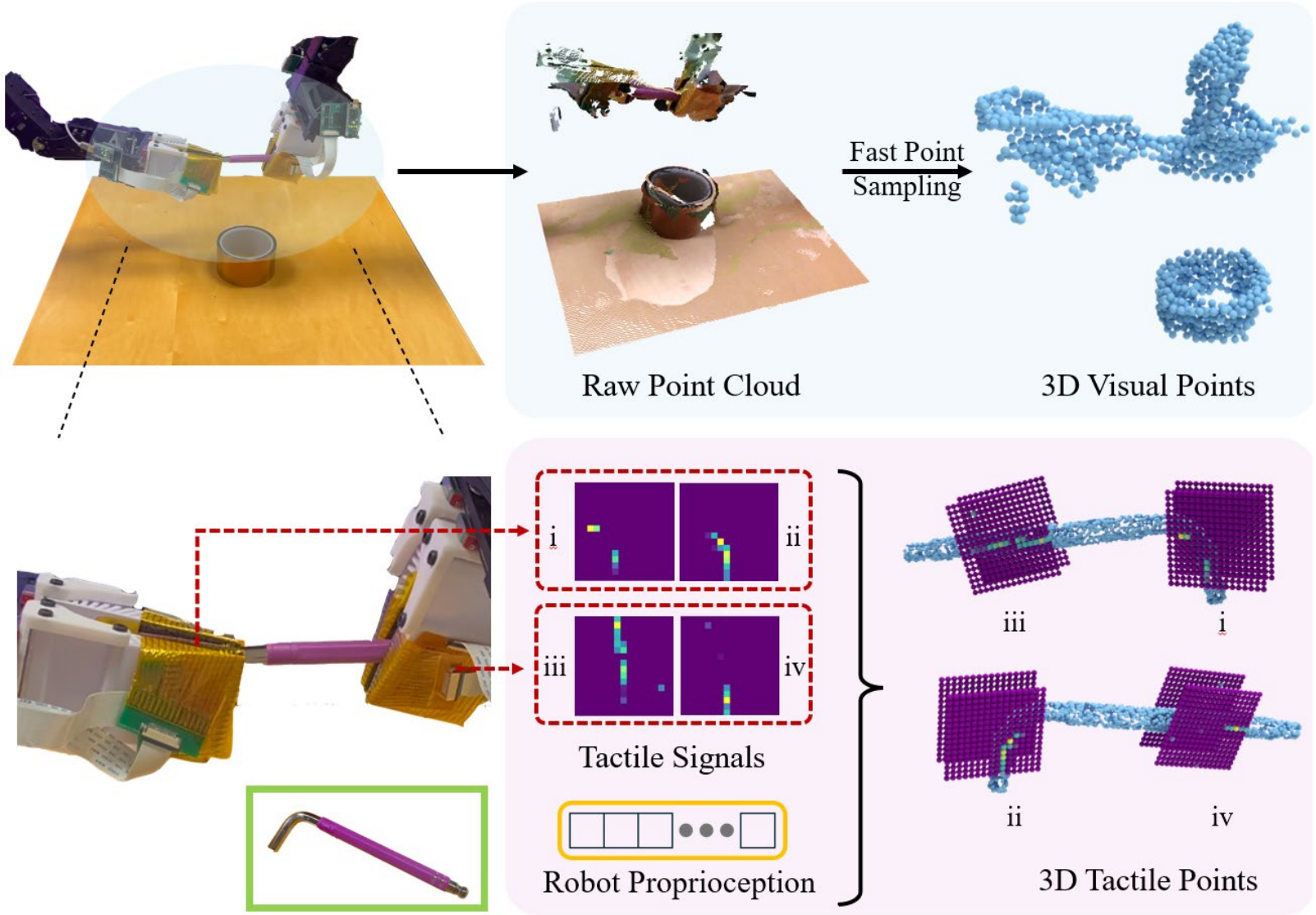

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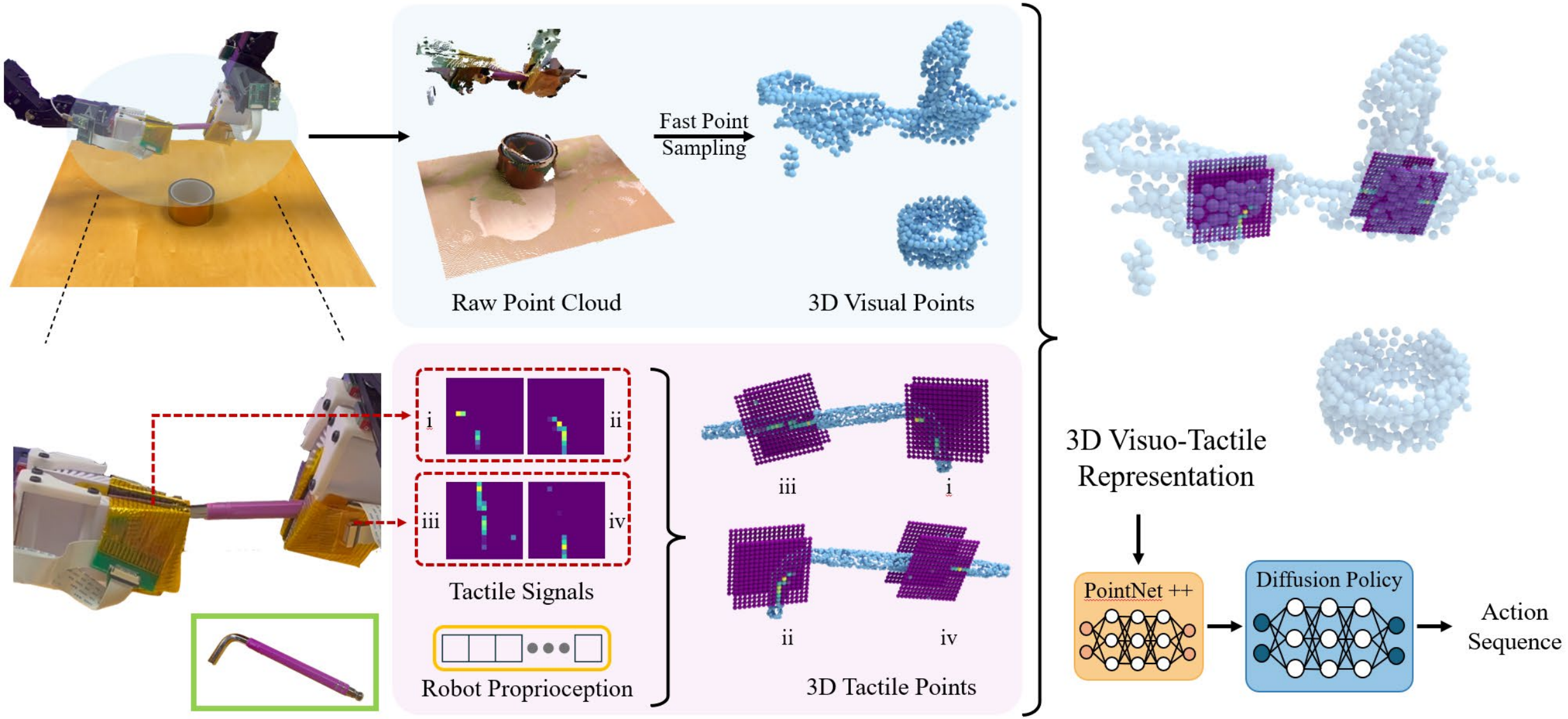
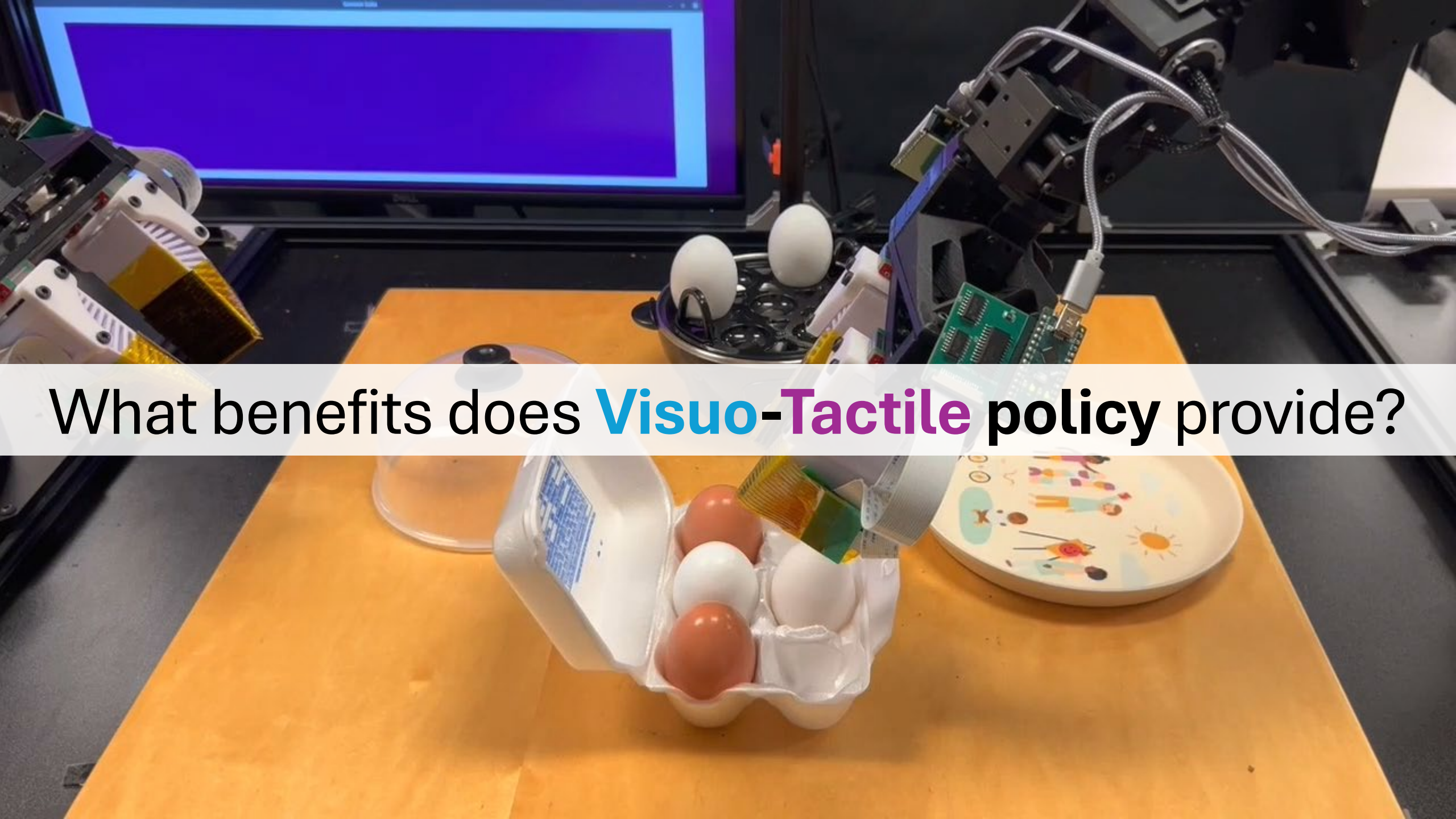
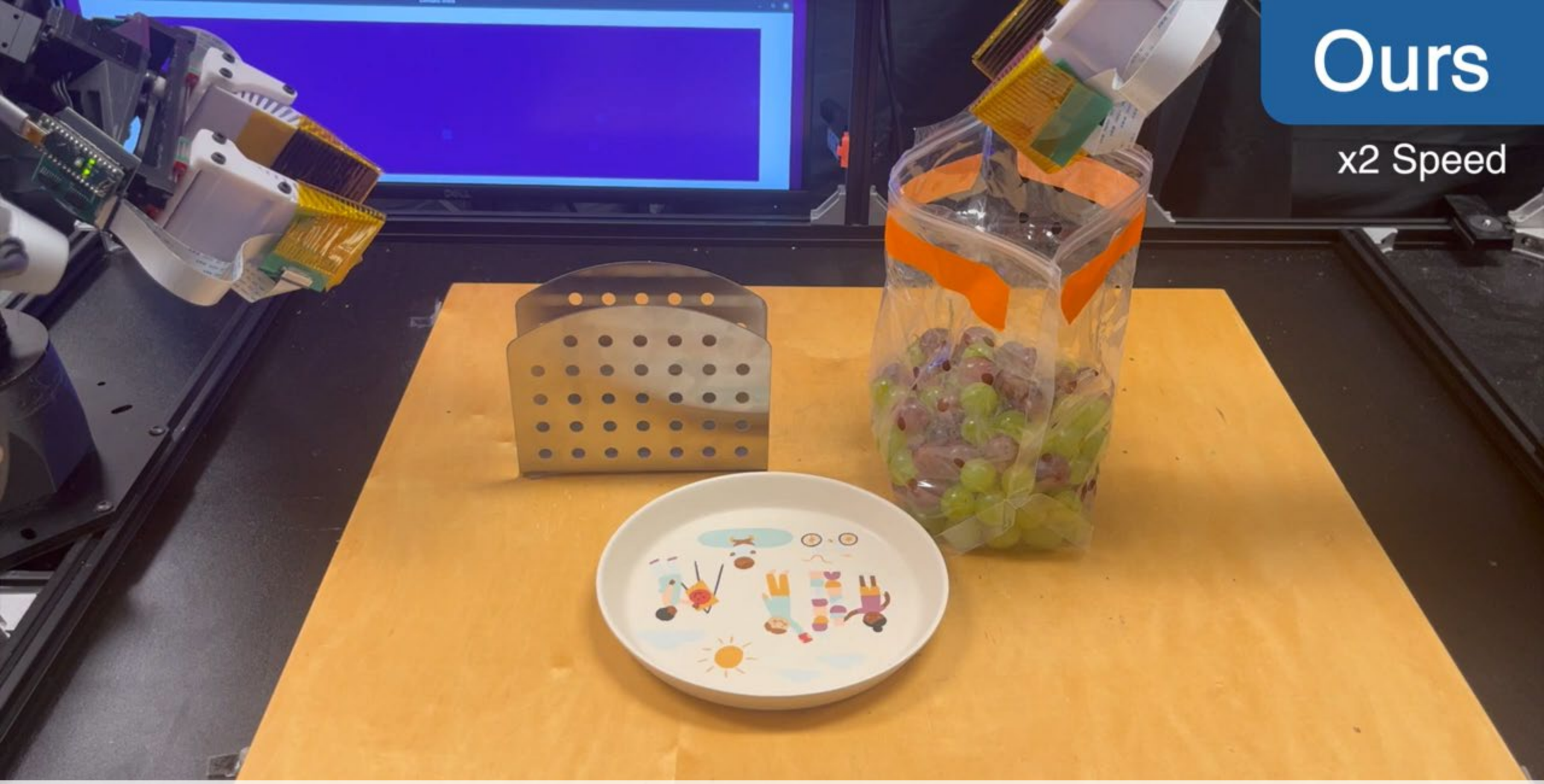
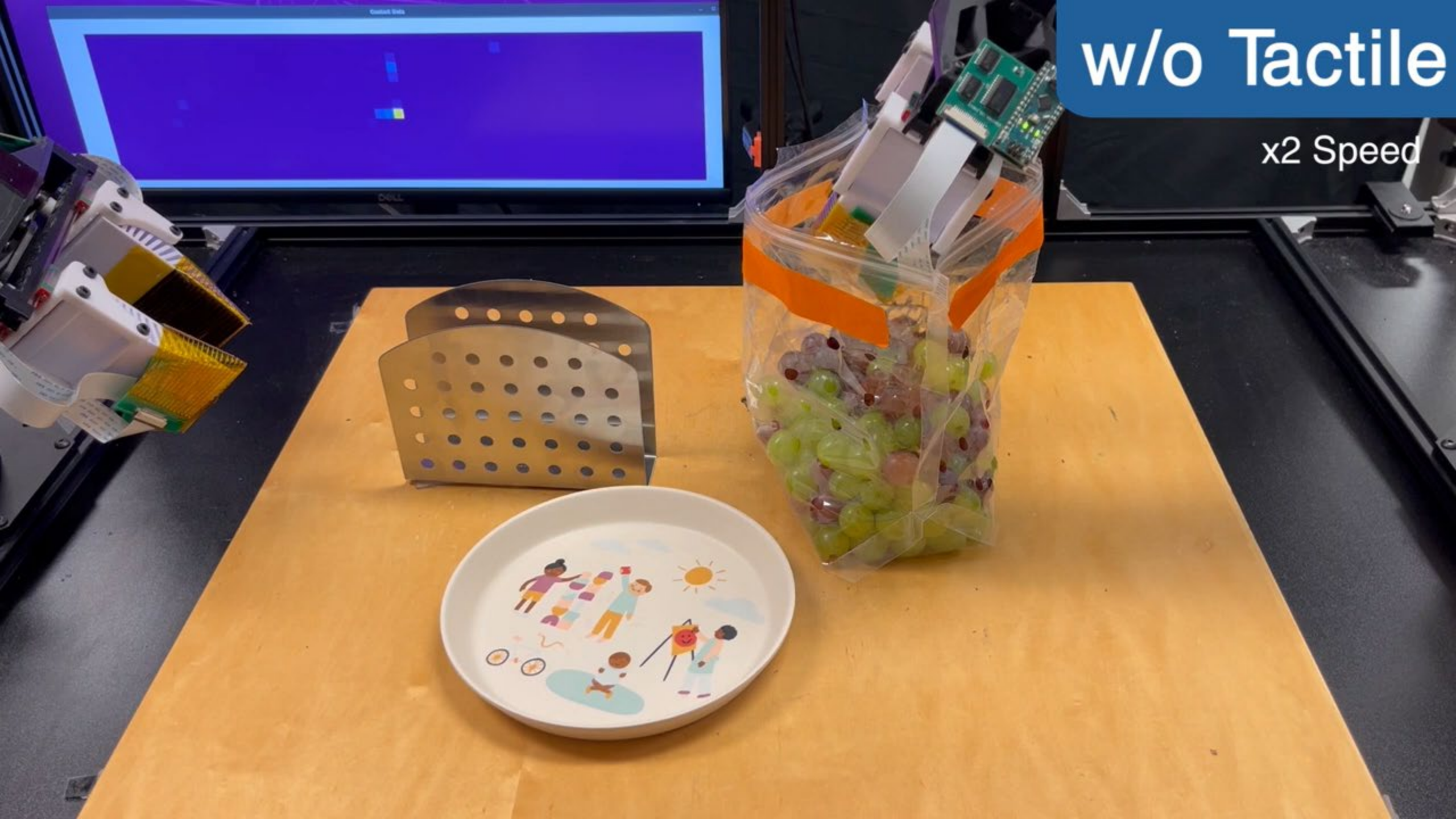


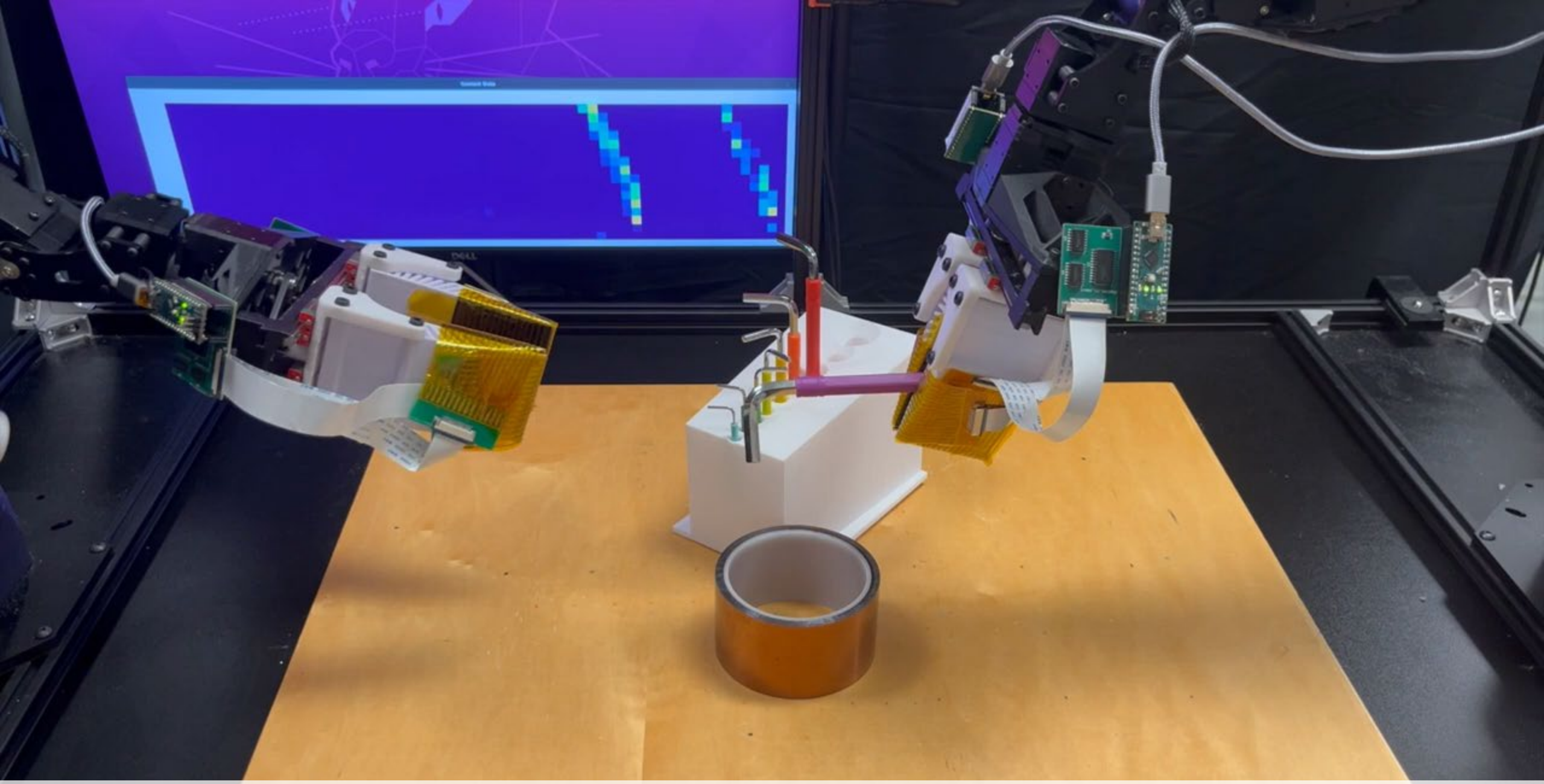
(a) Real World Environment (b) 3D Data Processing (c) Decision-Making Module


What benefits does Visuo-Tactile policy provide?

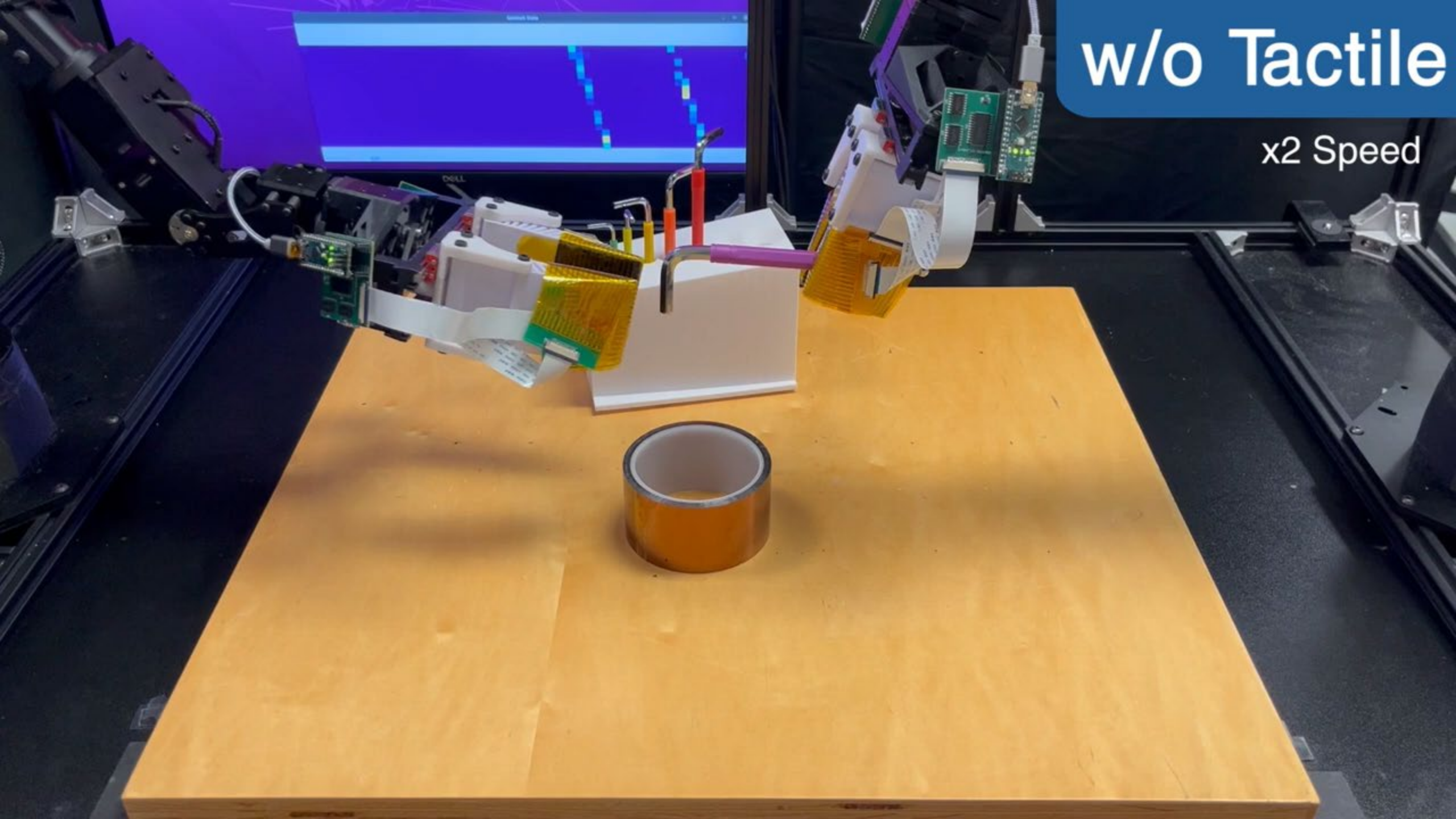


The robot can successfully grasp multiple grapes without broken


w/o Tactile
x2 Speed



A successful in-hand adjustment can secure the following insertion task


w/o Tactile
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Take Home Message for Robust Tactile Policy

1. Train yourself

-- to think and behave like the robot to feel

Take Home Message for Robust Tactile Policy

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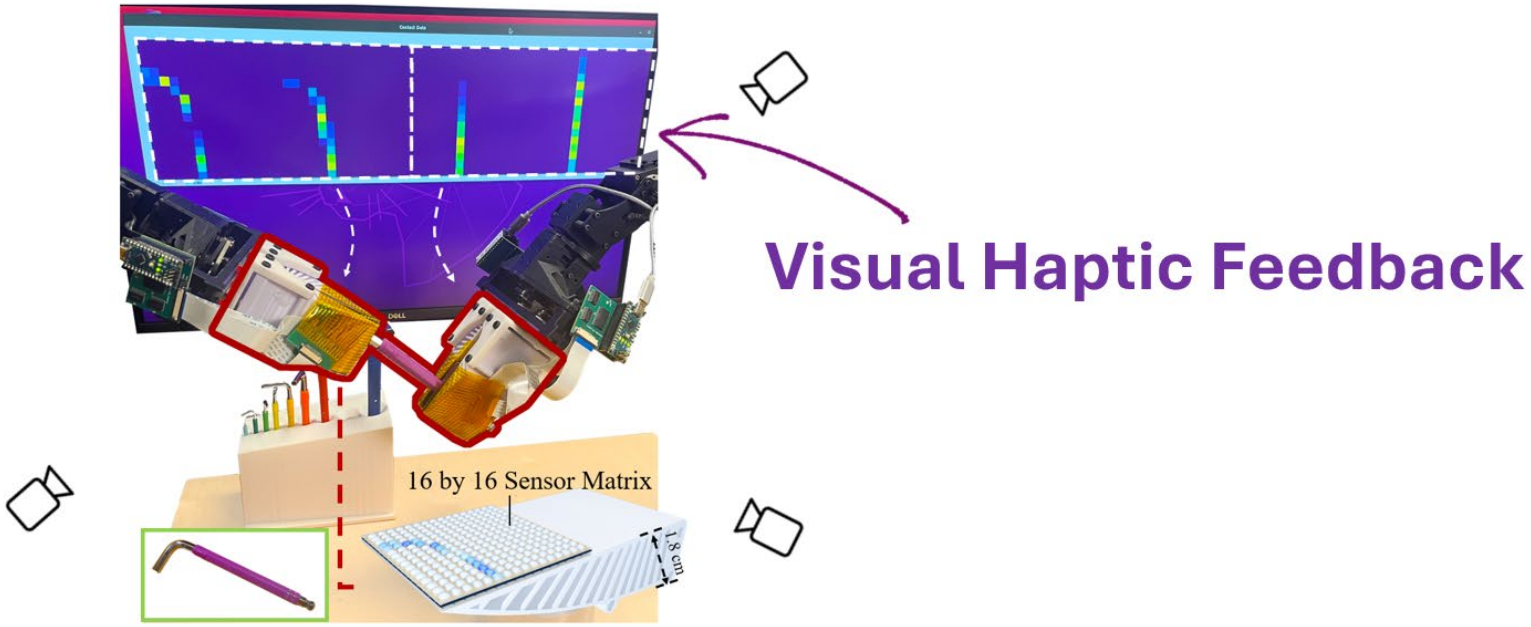
-- to think and behave like the robot to feel

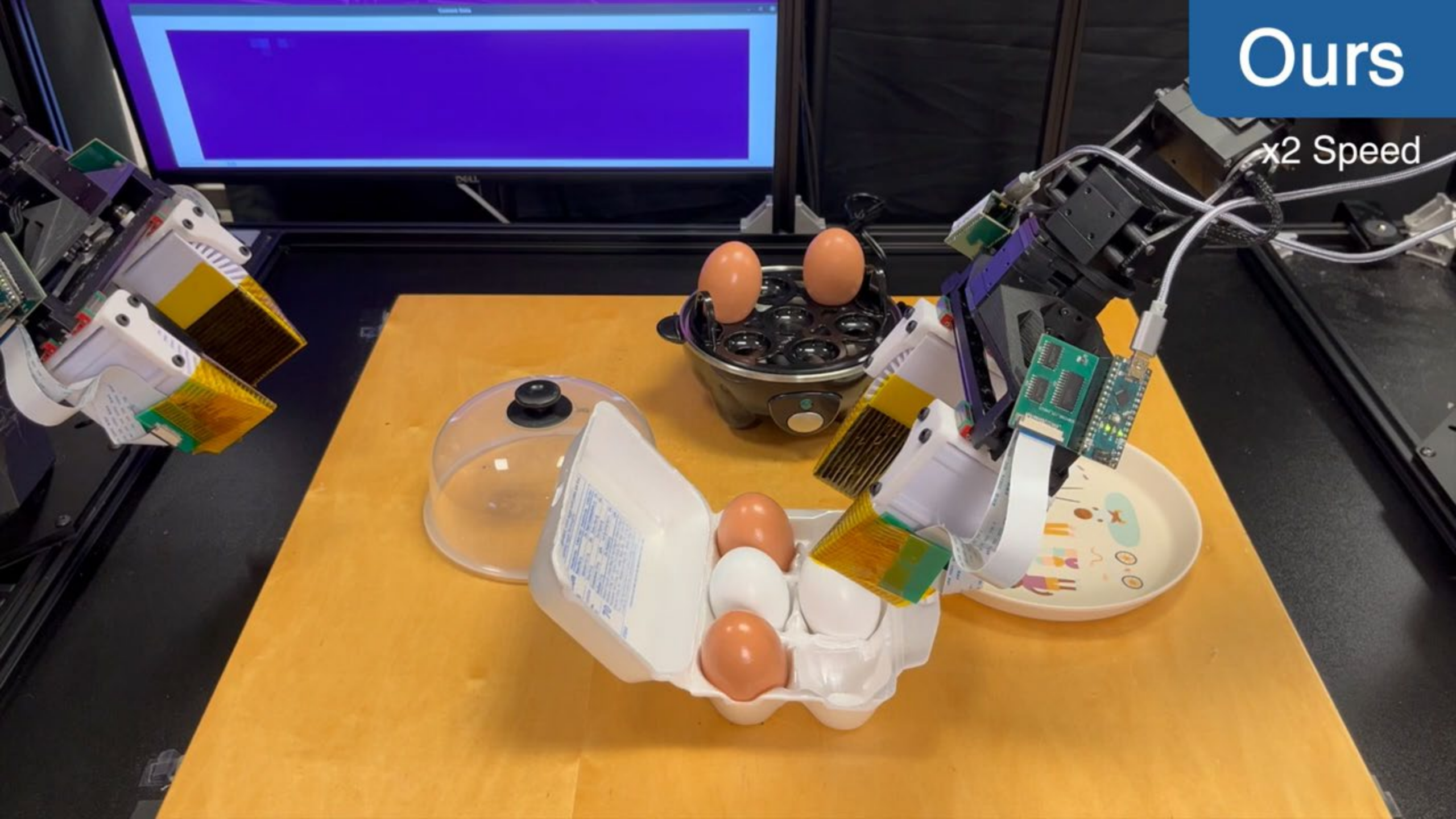
-- Use visual haptic feedback to enhance teleoperation



Take Home Message for Robust Tactile Policy

1. **Train yourself**
   -- to think and behave like the robot to feel
   -- Use haptic feedback to enhance teleoperation

2. Prepare for Failures
   -- e.g., re-grasp an egg if it drops)


Ours
x2 Speed

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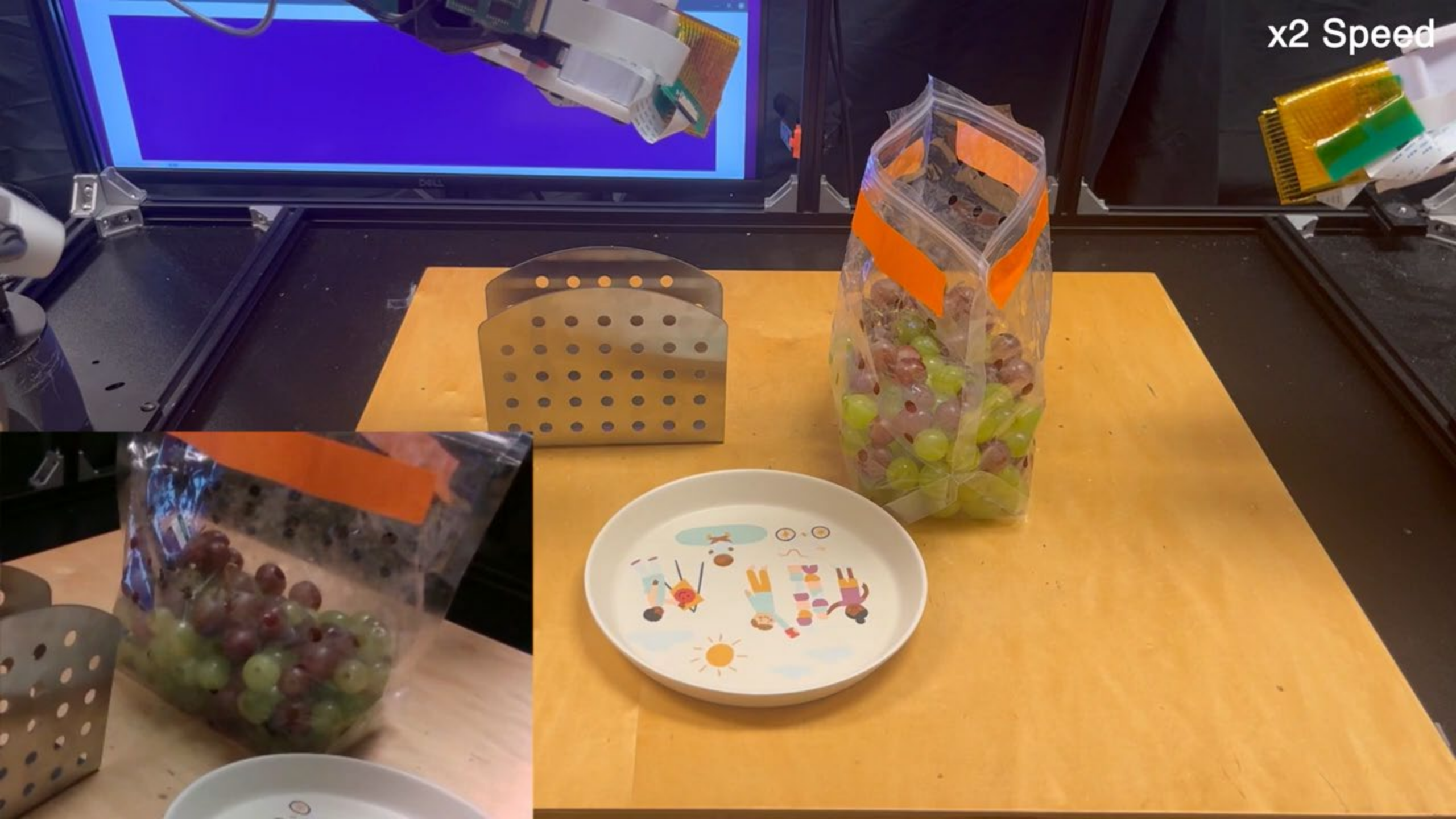
   -- to think and behave like the robot to feel
   -- Use haptic feedback to enhance teleoperation

2. **Prepare for Failures**
   -- e.g., re-grasp an egg if it drops)

3. Using tactile feedback to mitigate the negative impact of visual occlusion


x2 Speed

What I Wish I Had for Visual-Tactile Sensing

1. Tactile Hardware!

Robust and Scalable

2. Tactile Data!

Both in Sim and Real

3. Multi-Modal Representation!

Combine Vision and Touch

We hope to democratize our sensor to robot learning community!

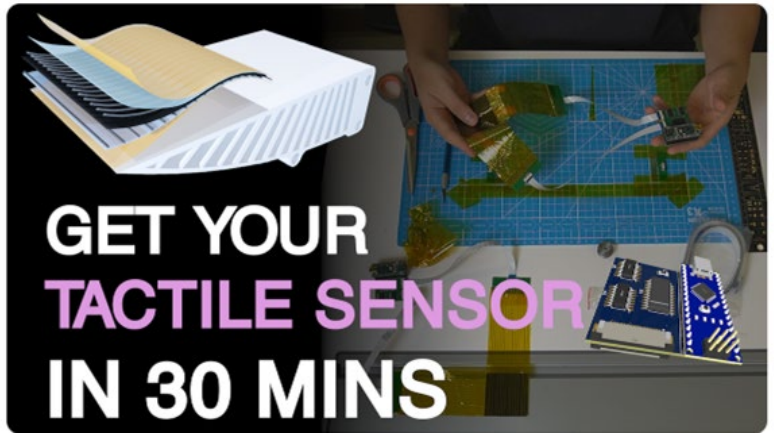
Reproduction Resources

Hardware Codebase

Hardware Guide

Bill of Materials

Sensor Fabrication and PCB Tutorial



Videos back from **both academia and industry**

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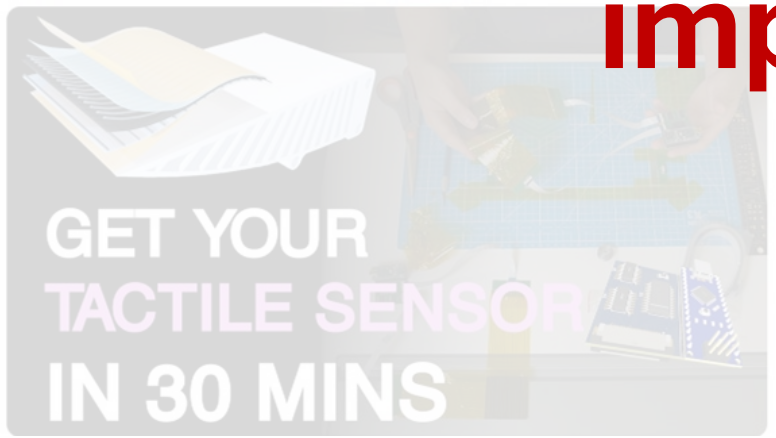

Videos back from **both academia and industry**

We are continuously improving our sensor!

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   Robust and Scalable

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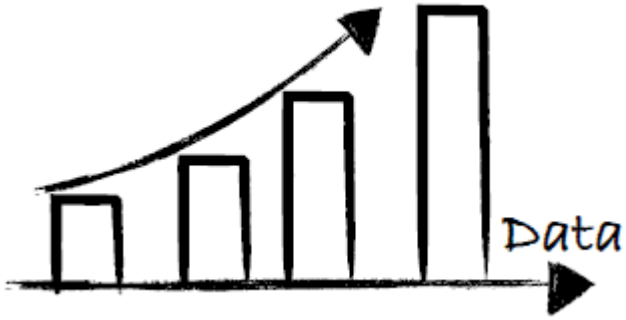
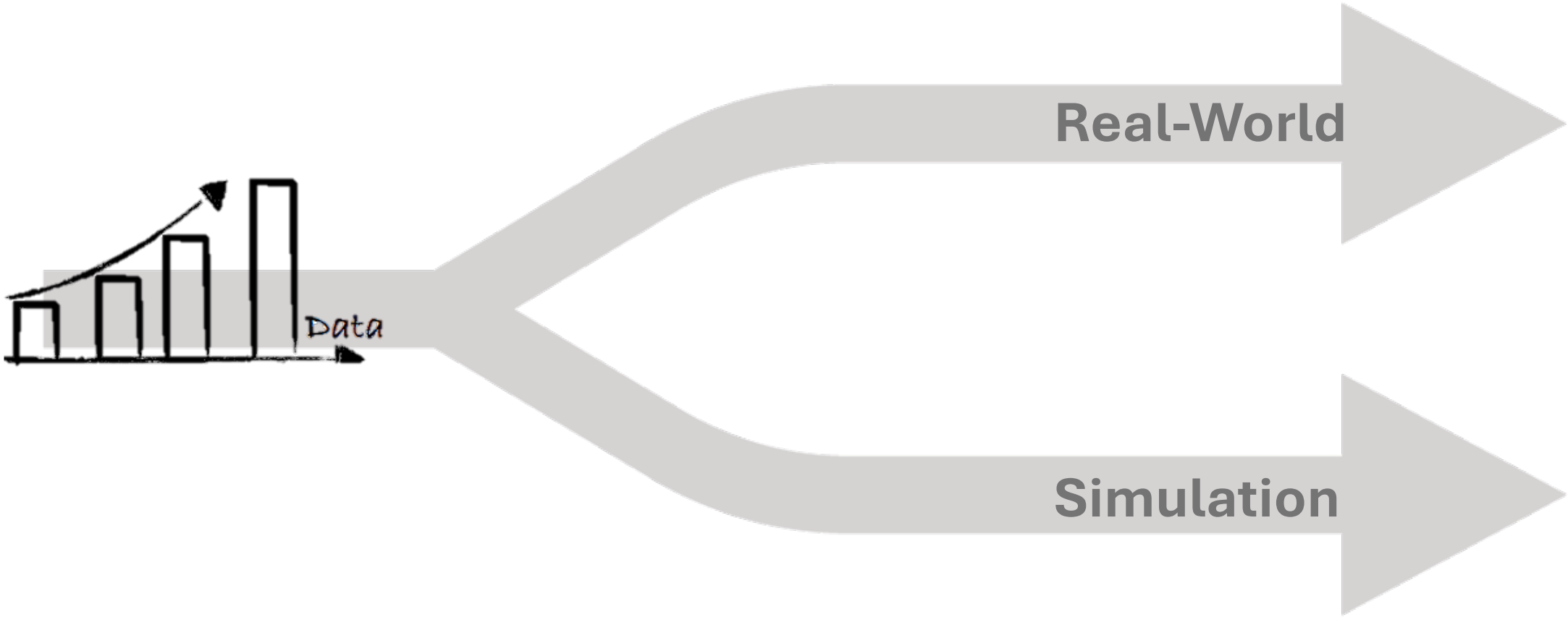


3. Representation!
   Combine Vision and Touch

Scaling Up Tactile Data



Scaling Up Real Tactile Data

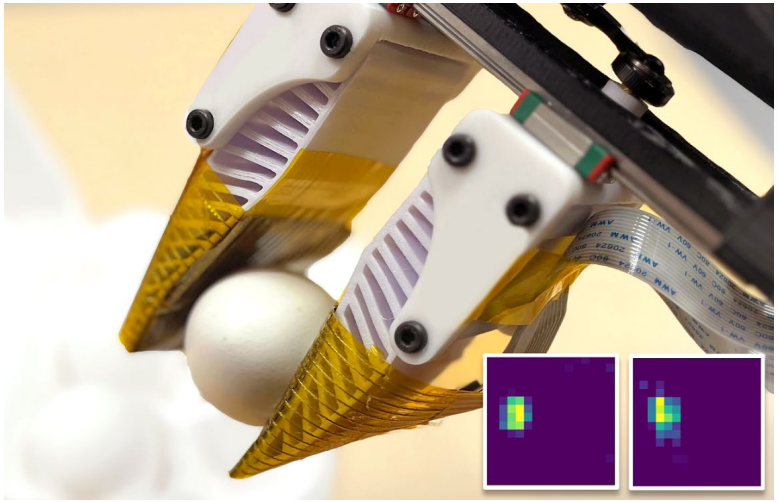
Scaling Up Real Tactile Data

UMI Gripper

Scaling Up Real Tactile Data

UMI Gripper

+



Flexible Tactile

=

?

Scaling Up Real Tactile Data

UMI Gripper

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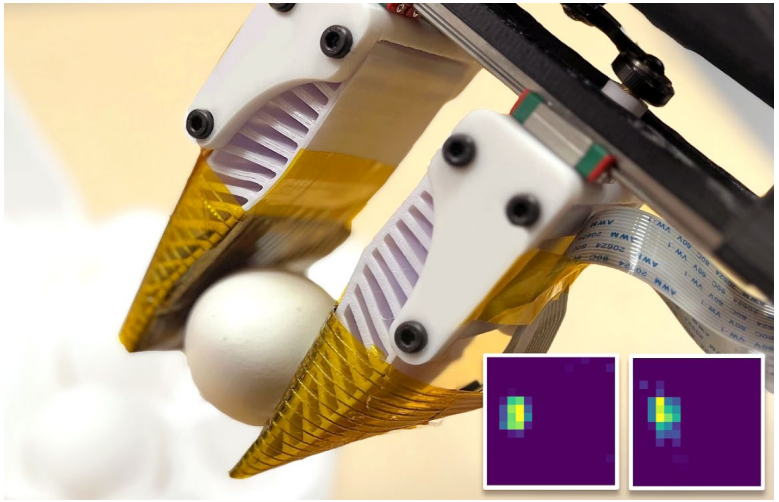

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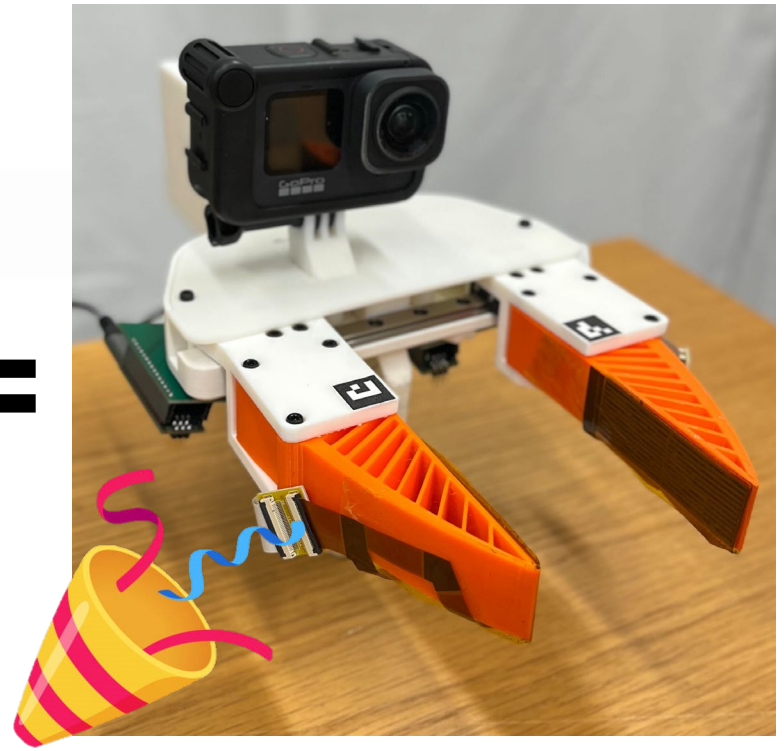
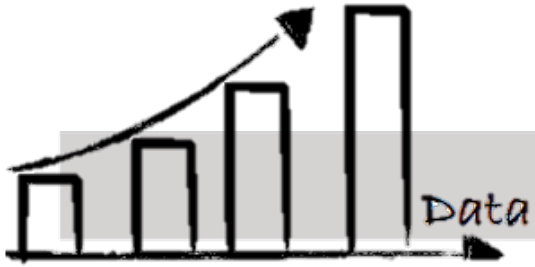


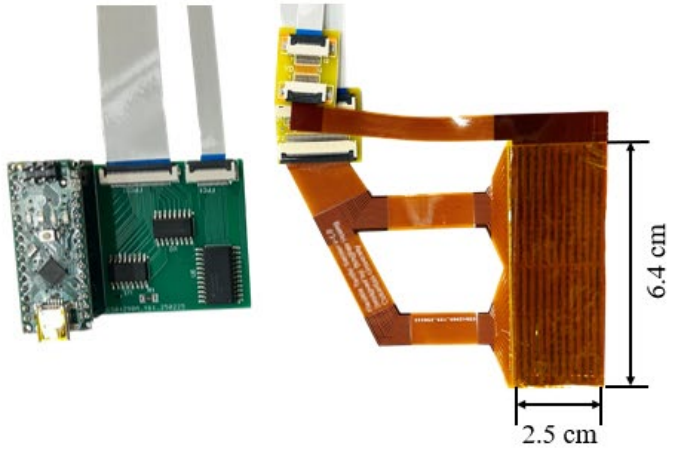
Scaling Up Real Tactile Data

Real-World

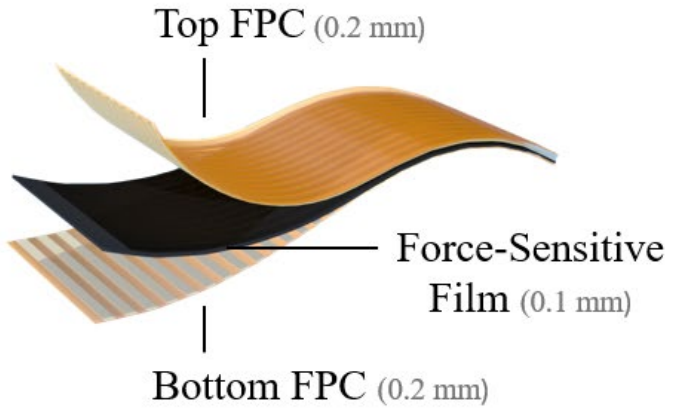


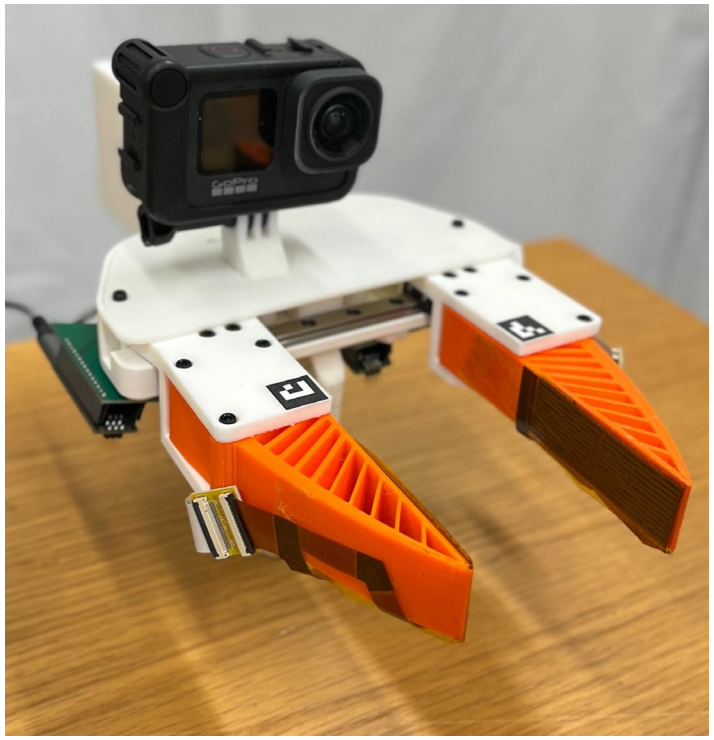
(a) Tactile Hardware

(i)

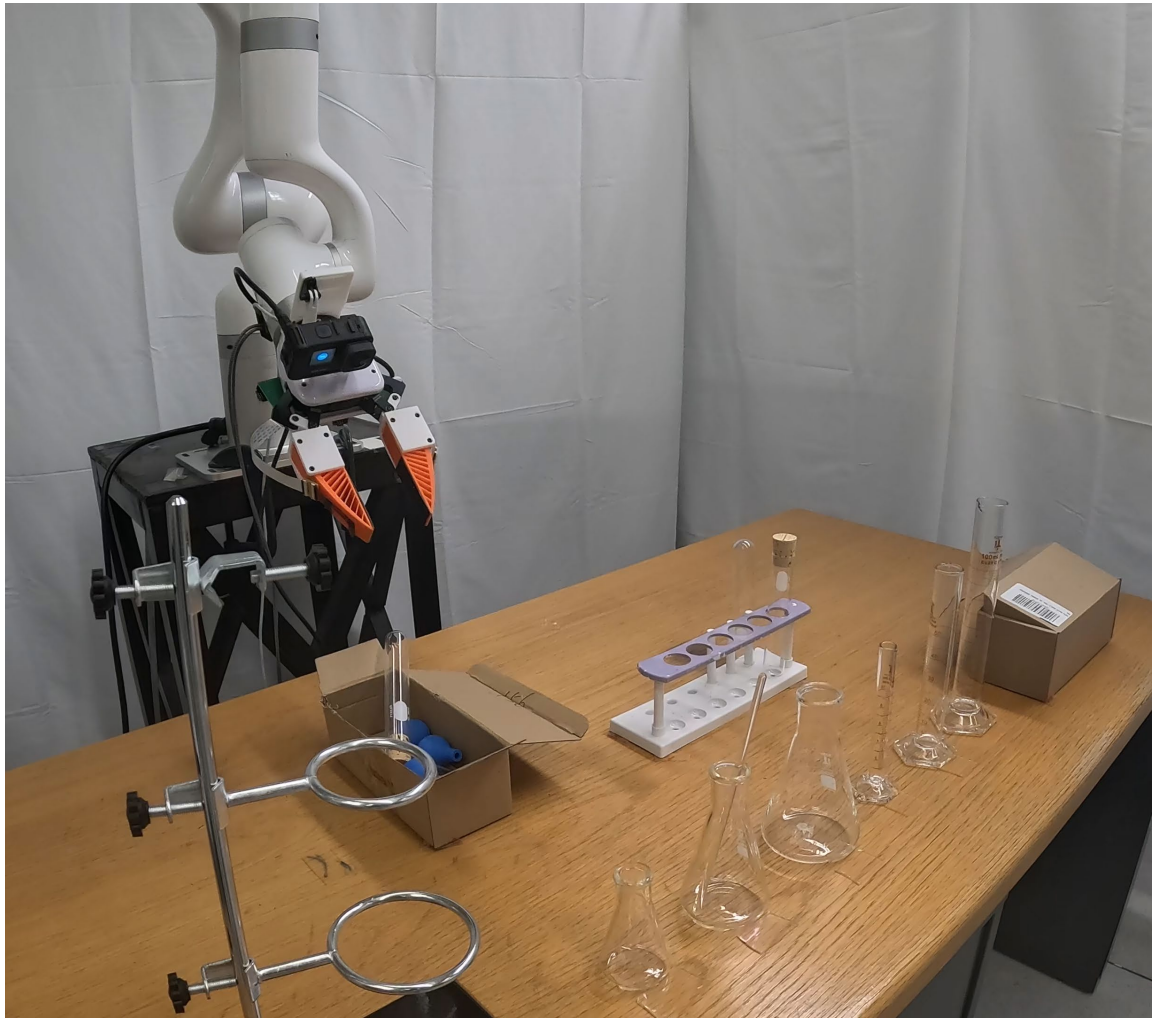


(ii)

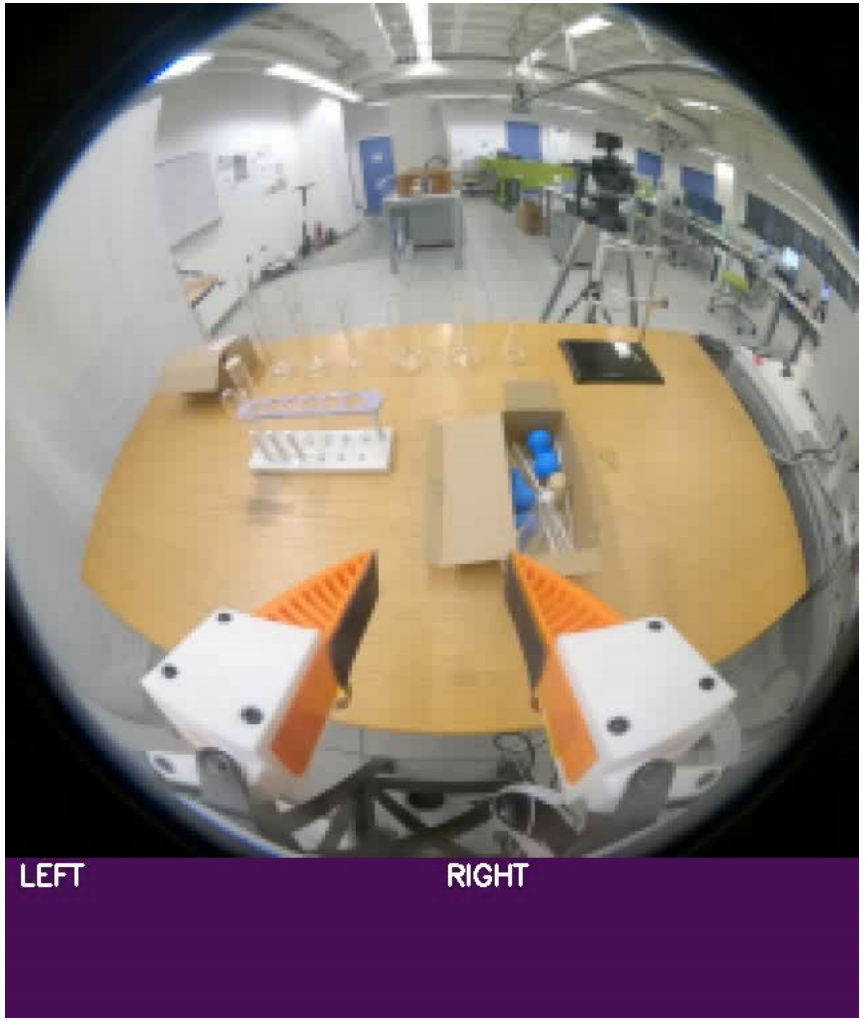




Scaling Up Real Tactile Data



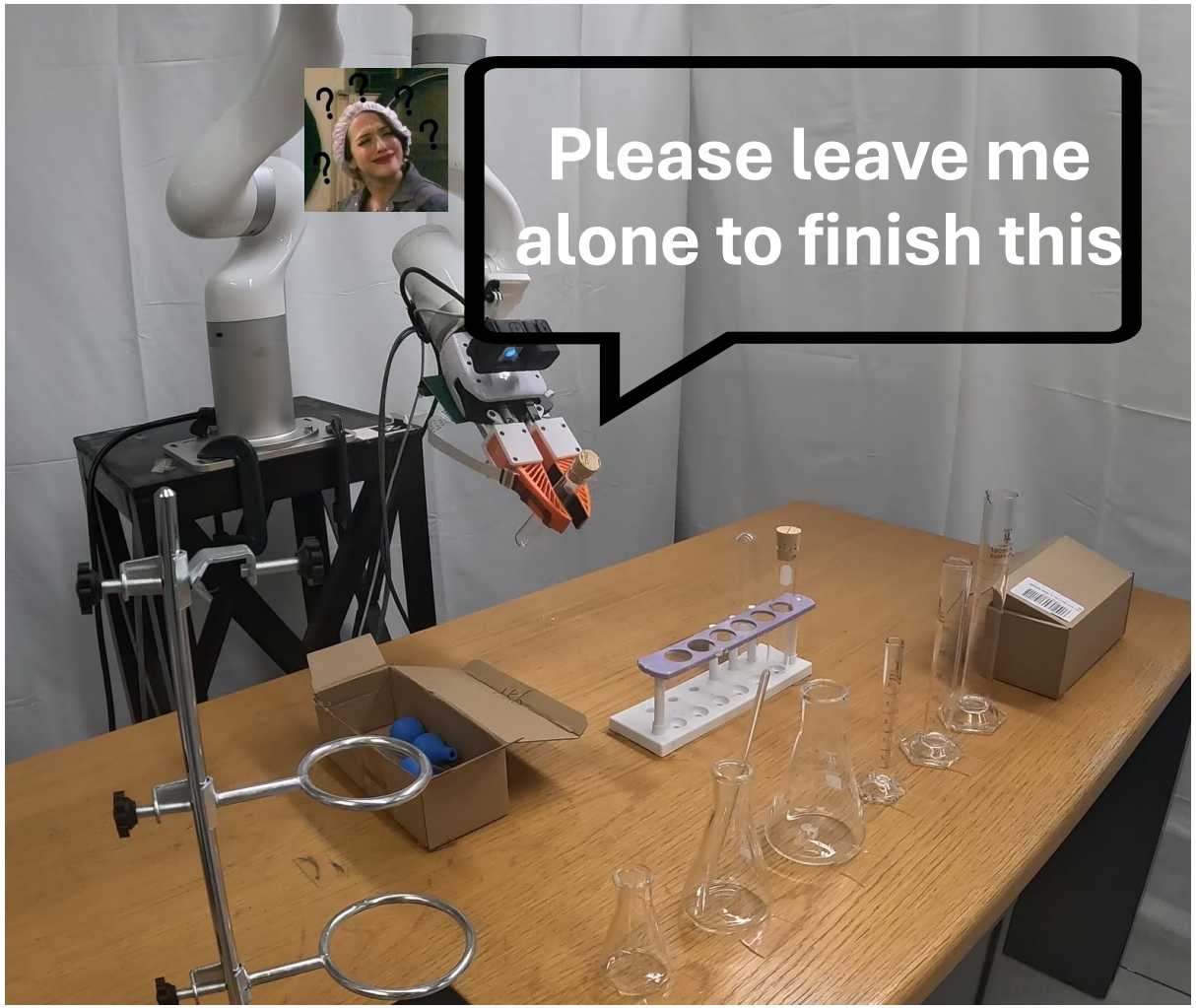
In-Hand Reorientation and Insertion



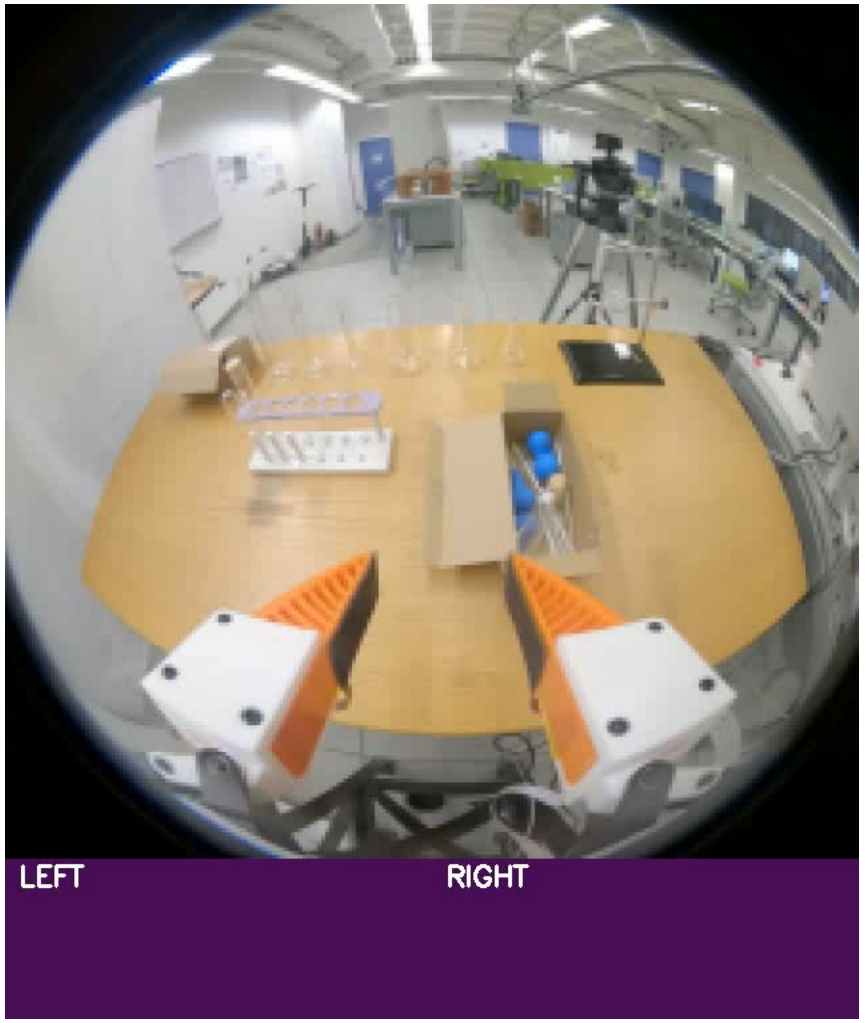
Human Interference Test

Videos credit to Yolanda

Scaling Up Real Tactile Data



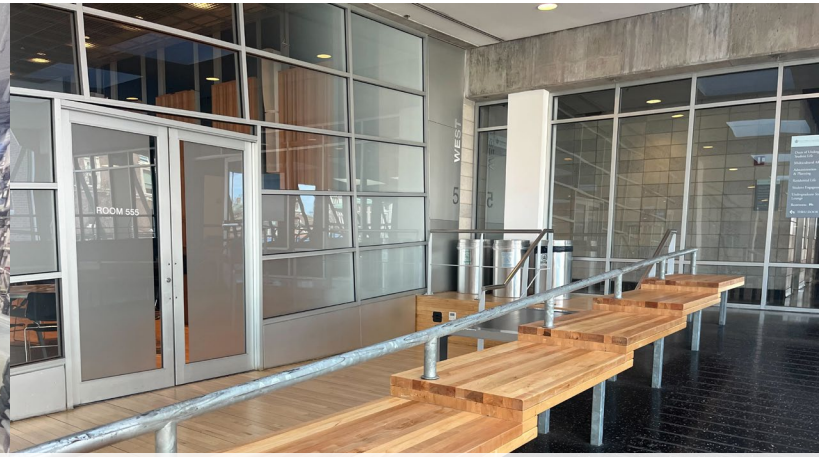
In-Hand Reorientation and Insertion



Human Interference Test

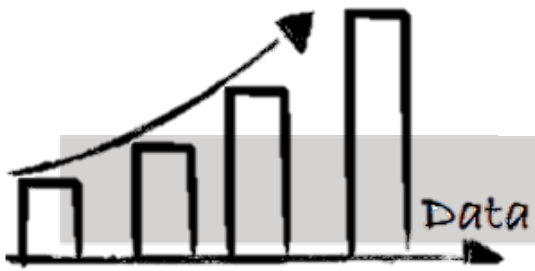
Videos credit to Yolanda

Scaling Up Real Tactile Data



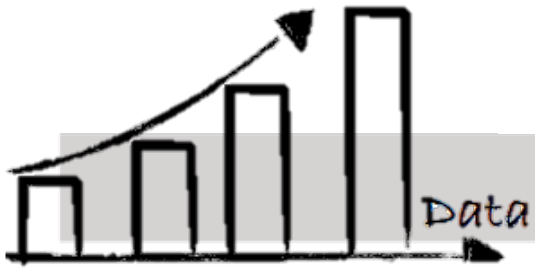
Making Wild Tactile Data Collection Possible

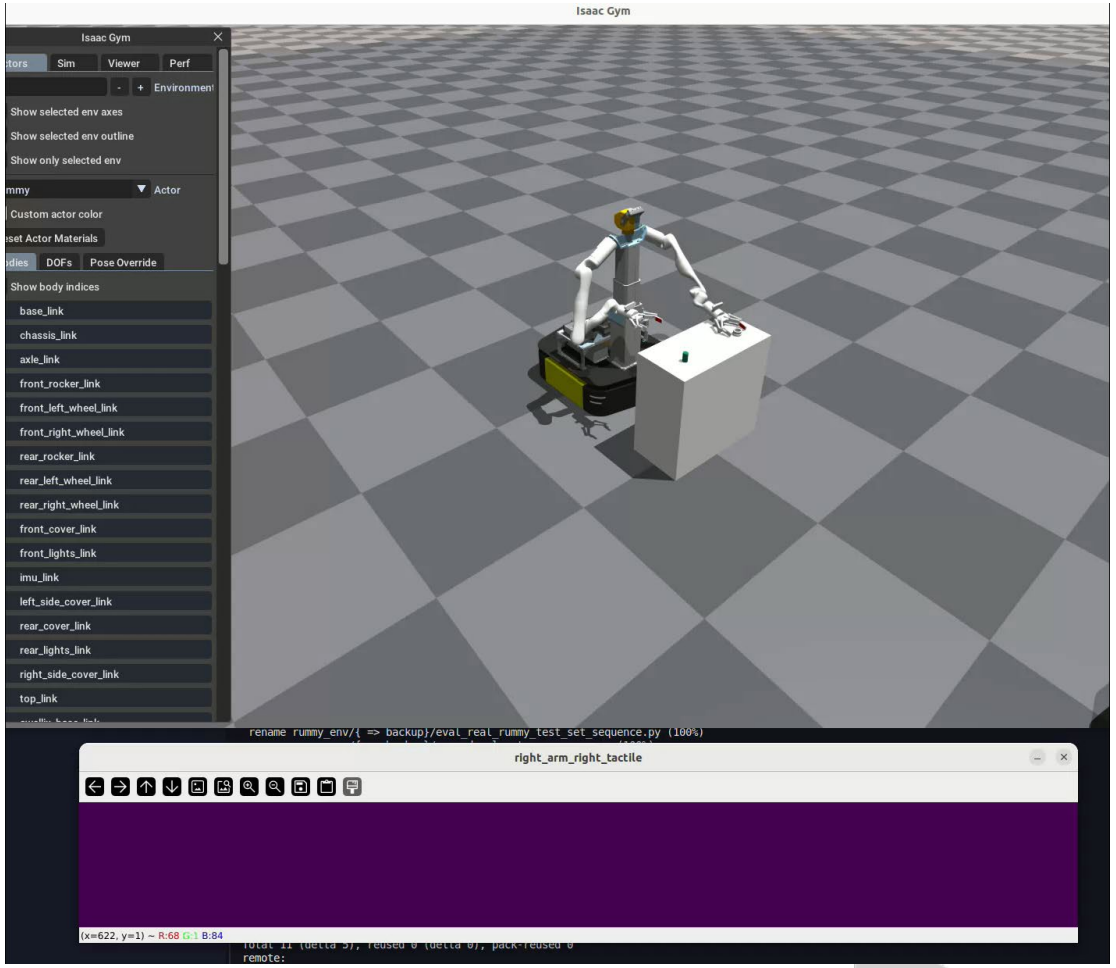
Scaling Up Sim Tactile Data



Simulation

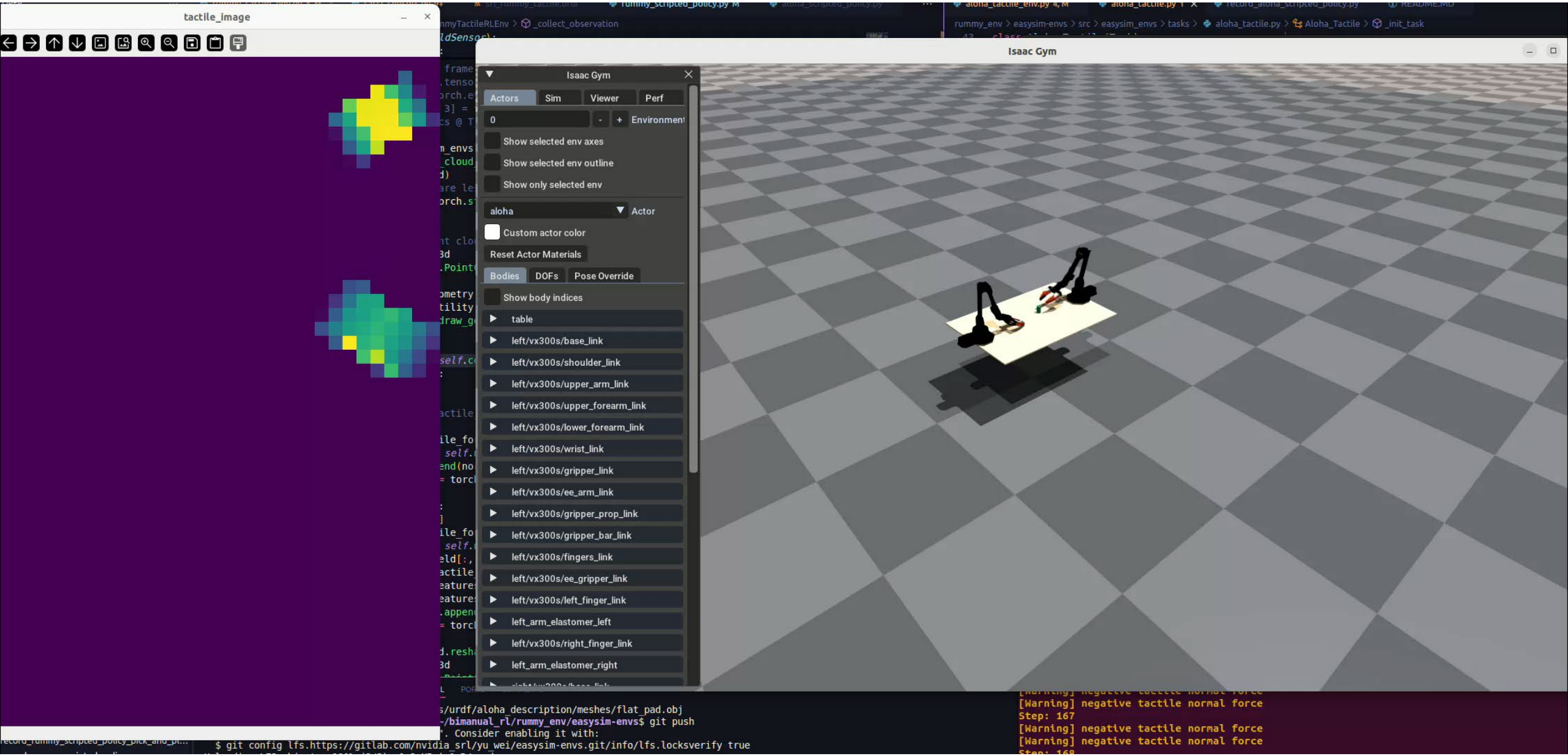
Scaling Up Sim Tactile Data



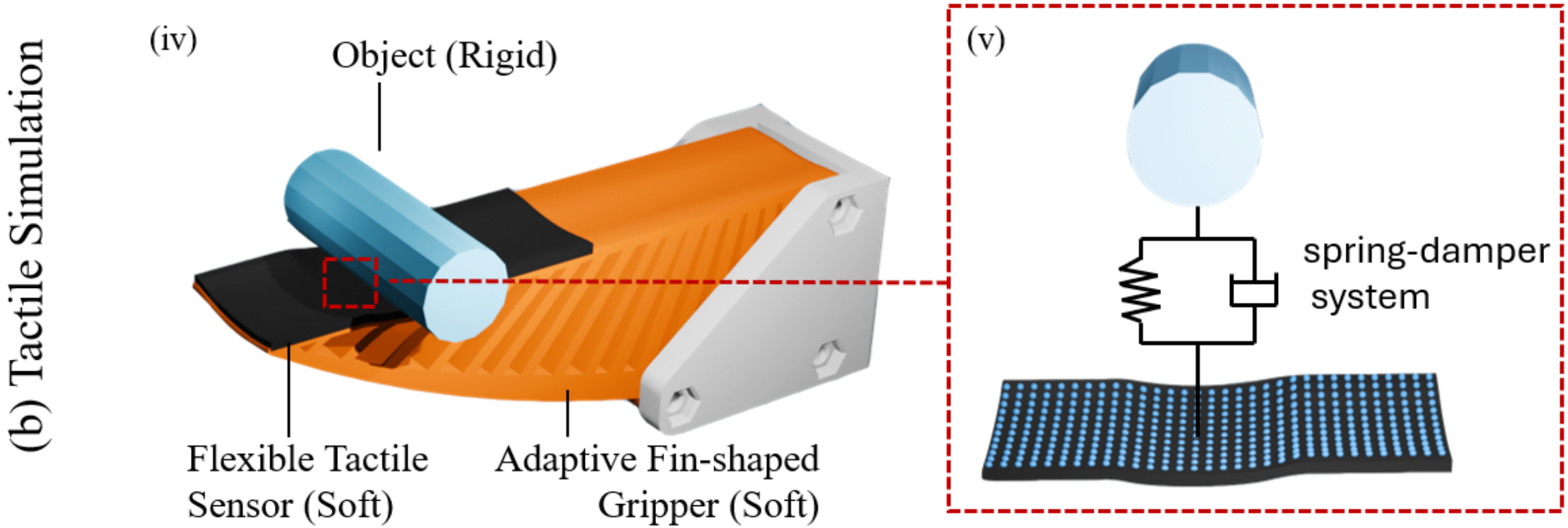


Simulation

Tactile Simulation



Scaling Up Sim Tactile Data



Simulate Compliance!

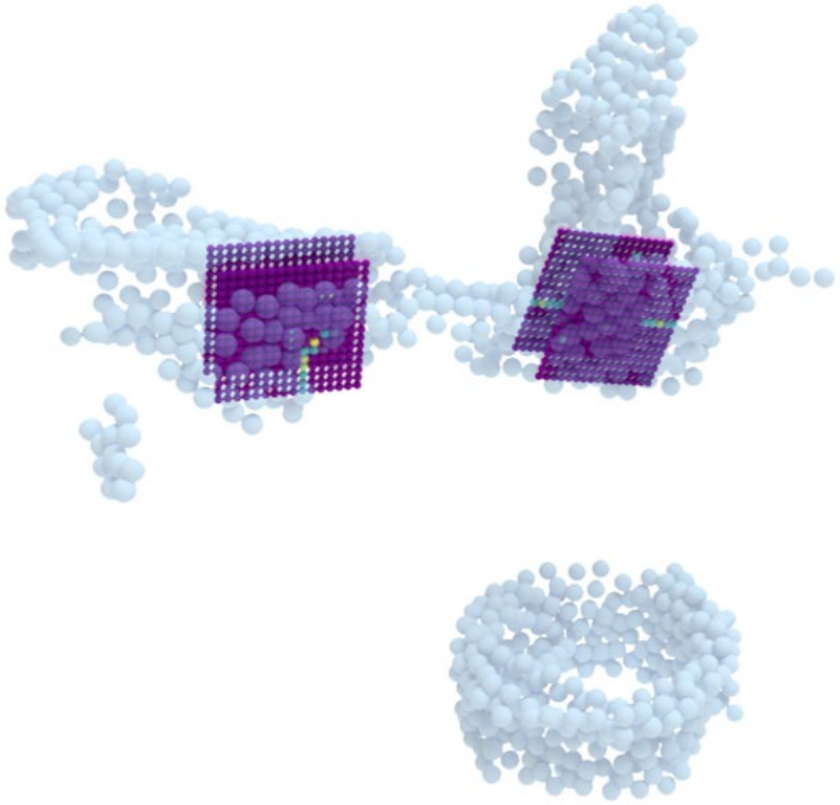
What I Wish I Had for Visual-Tactile Sensing

1. Tactile Hardware!
   Robust and Scalable

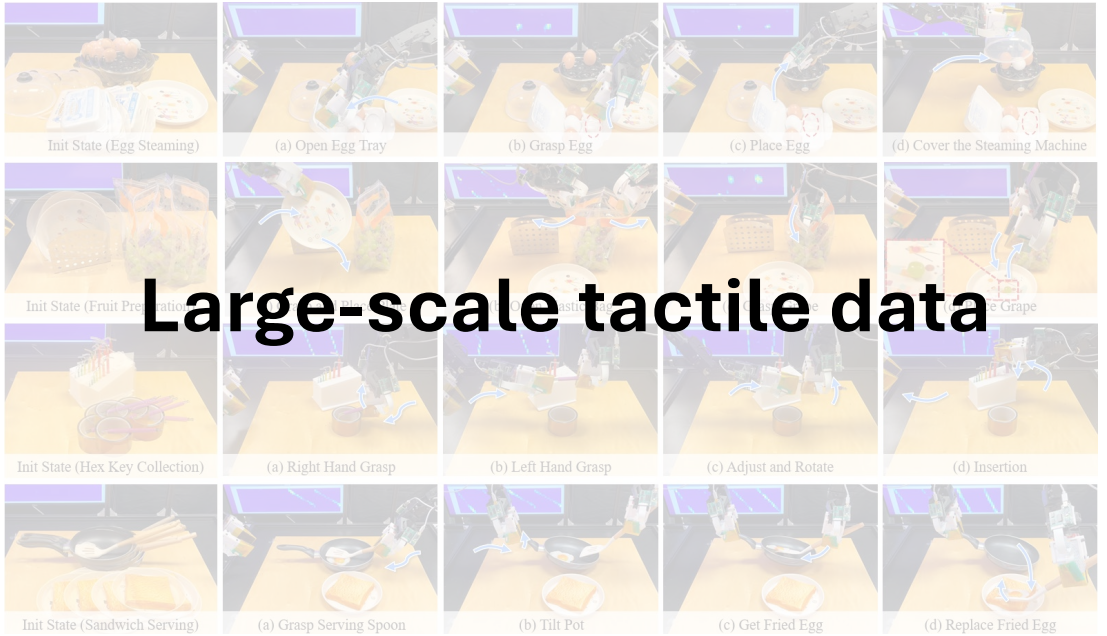
2. Tactile Data!
   Both in Sim and Real

3. Multi-Modal Representation!
Combine Vision and Touch

Combine Vision and Touch

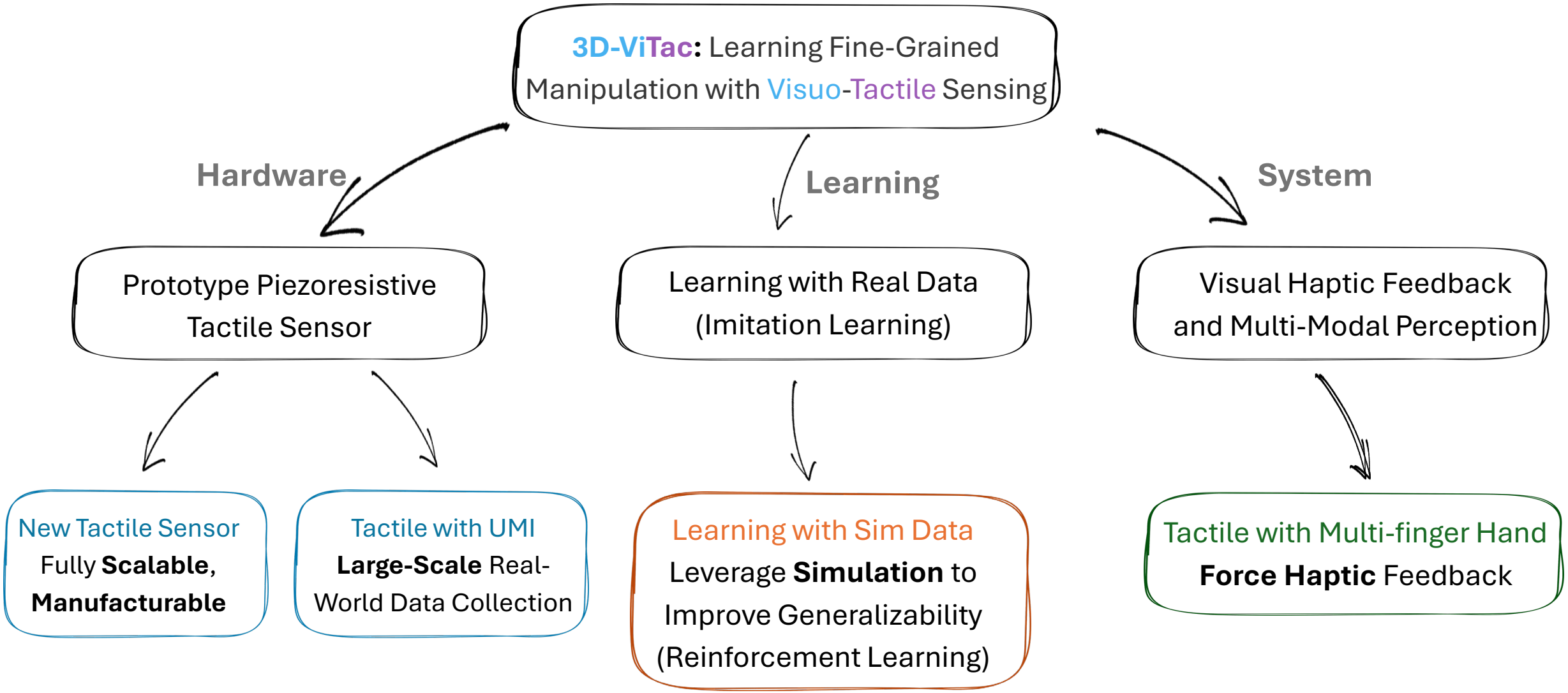


Early Fusion



Large-scale tactile data

Pretrain Tactile Encoder


3D-ViTac: Learning Fine-Grained Manipulation with Visuo-Tactile Sensing
Hardware
Learning
System
Prototype Piezoresistive Tactile Sensor
Learning with Real Data (Imitation Learning)
Visual Haptic Feedback and Multi-Modal Perception
New Tactile Sensor Fully Scalable, Manufacturable
Tactile with UMI Large-Scale Real-World Data Collection
Learning with Sim Data Leverage Simulation to Improve Generalizability (Reinforcement Learning)
Tactile with Multi-finger Hand Force Haptic Feedback