

Learning Heterogeneous Tactile Representations with Graph Neural Networks for Dexterous Manipulation

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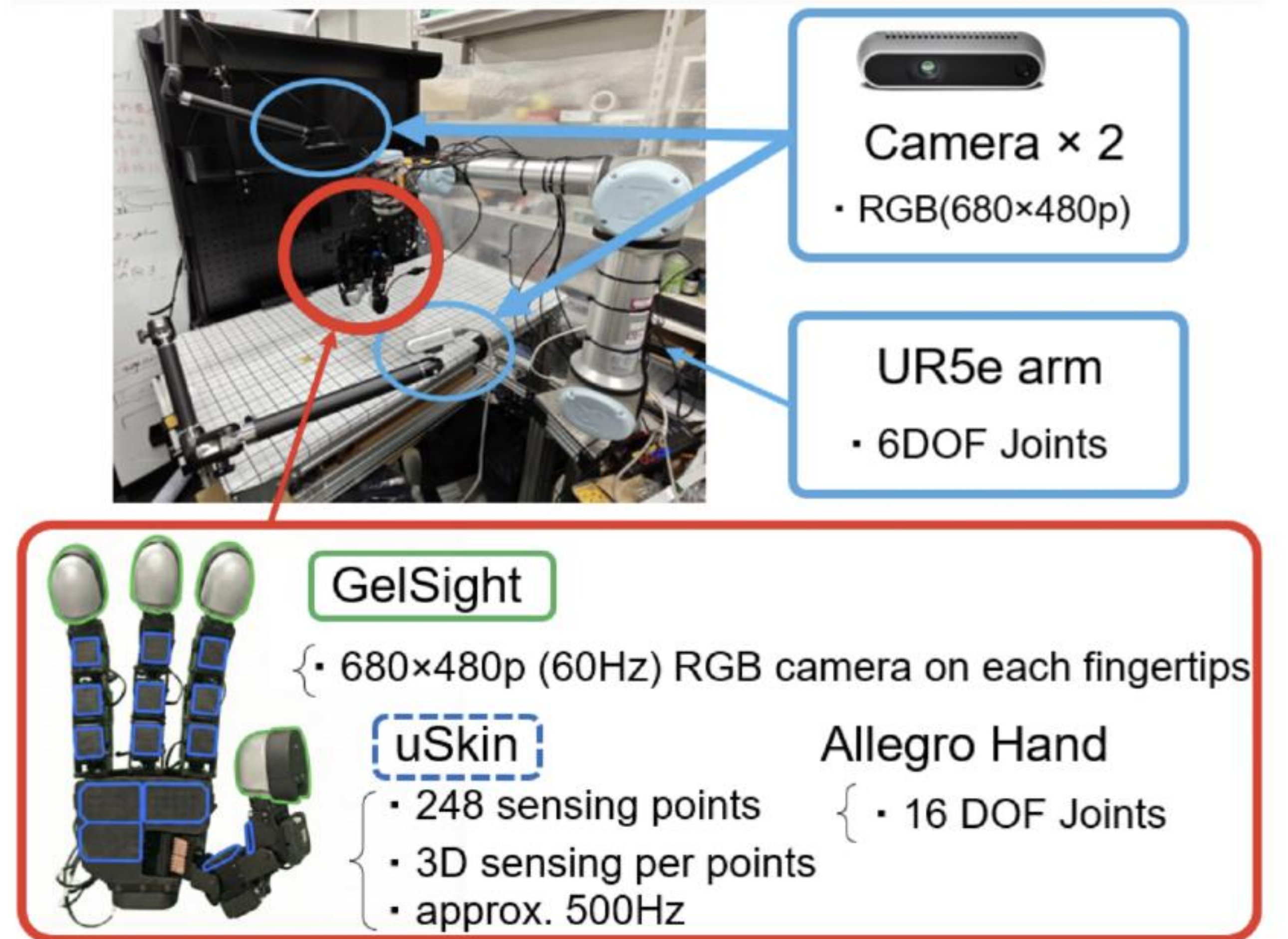


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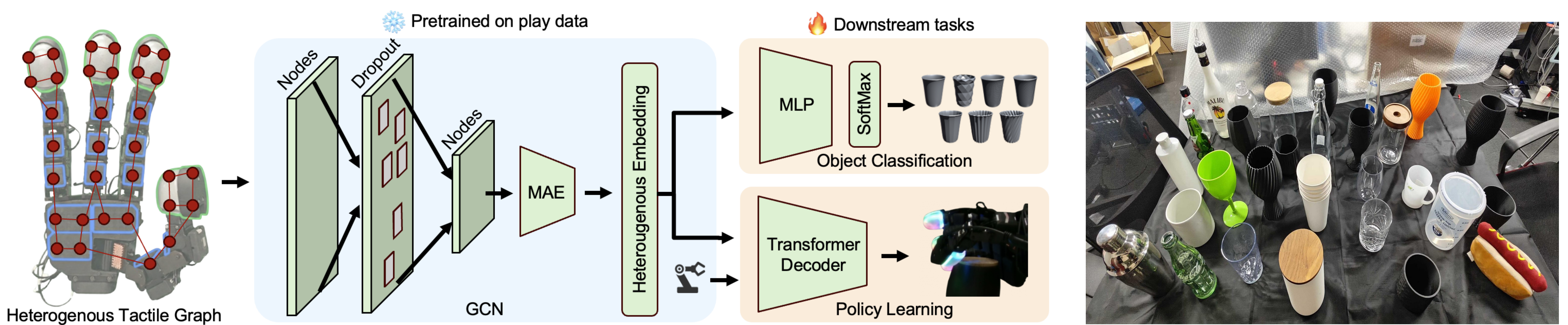
Introduction

- Tactile feedback is essential for dexterous manipulation, since vision alone cannot capture contact-level cues such as force, slip, friction, and surface deformation.
- Most tactile representation methods focus on a single sensor type**, limiting their ability to capture the full contact state
- We propose a **heterogeneous tactile graph representation** that fuses palm uSkin taxels with fingertip vision-based tactile sensors to learn a unified tactile embedding.

System Overview



Network Architecture



We pre-train a **heterogeneous tactile graph encoder** on 30 objects and 25 minutes of data that fuses fingertip vision-tactile features and palm uSkin taxels into a unified tactile embedding.

Experimental Result

Object Classification



We test our system's ability to classify textured object using various 3D printed cups.

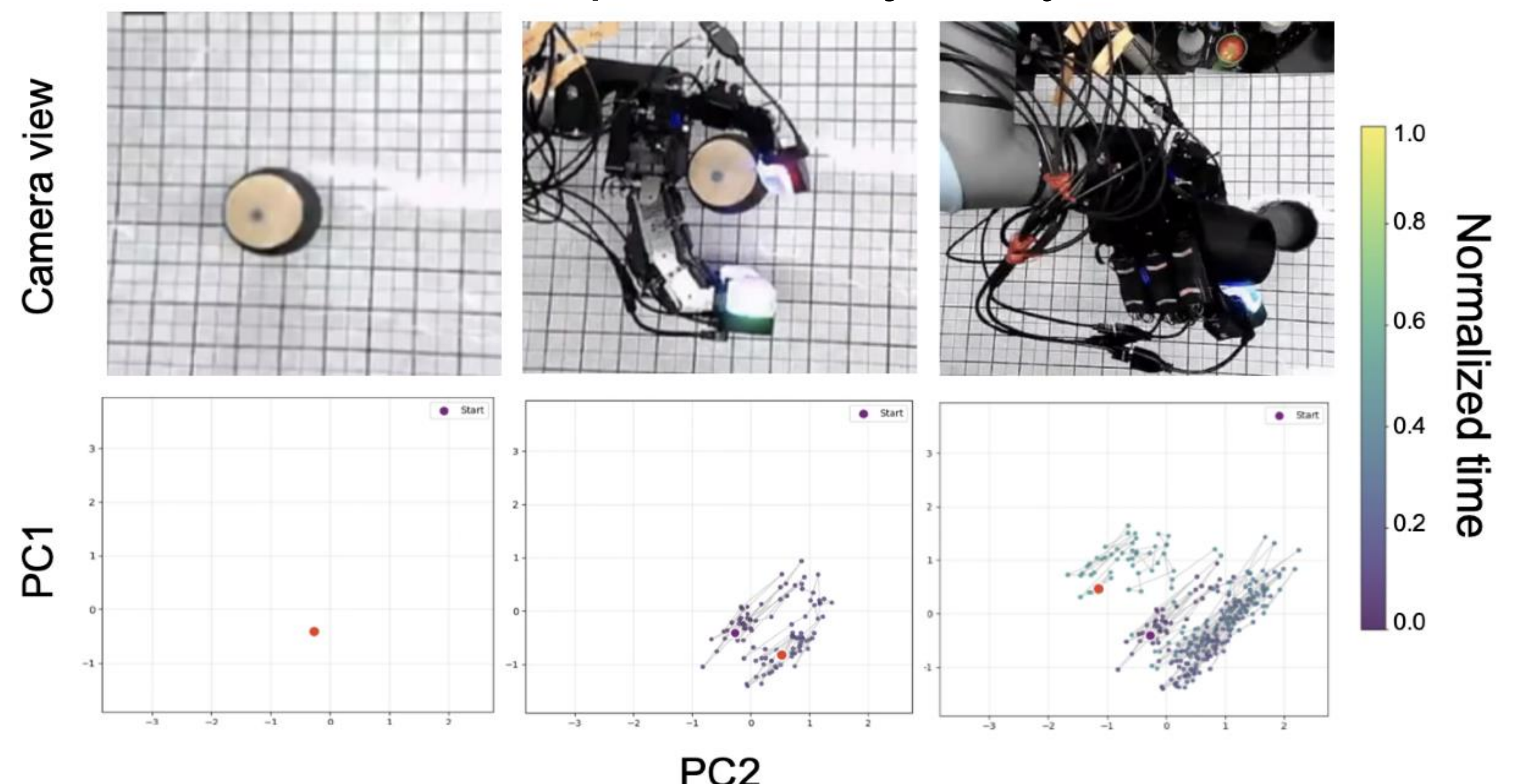
Class	Precision	Recall	F1-score
Original Cup	1.000	1.000	1.000
Standard Cup	0.988	0.995	0.992
Low-Poly Cup	0.999	1.000	0.999
Cup with Double Strip Deformation	1.000	1.000	1.000
Cup with Single Strip Deformation	1.000	0.952	0.975
Polygonal Cup	0.954	1.000	0.976
Wavy Cup	1.000	1.000	1.000
Wavy Twisted Cup	1.000	0.982	0.991

The frozen heterogeneous tactile embedding achieved near-perfect classification across eight cup variants, showing that it captures meaningful geometric and contact differences.

Latent Space Analysis During Manipulation



Teleoperated trajectory



During manipulation, the tactile latent space moved from a **compact pre-contact region**, to a **distinct palm-grasp contact region**, and then spread further as the fingertips opened the lid and poured, showing step-by-step contact transition encoding.