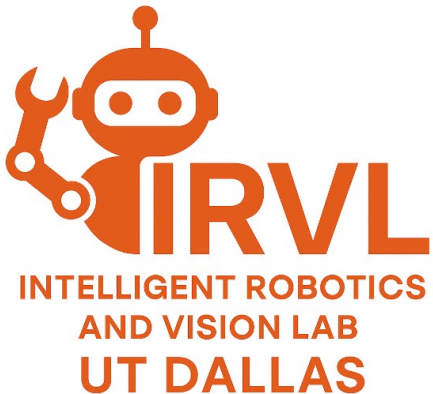


Cross-Embodiment Robot Manipulation via a Unified Hand Action Space

Luis Felipe Casas¹, Robert Teal¹, Keval Shah¹, Abhijit Tadepalli²

Wanxin Jin², Yu Xiang¹

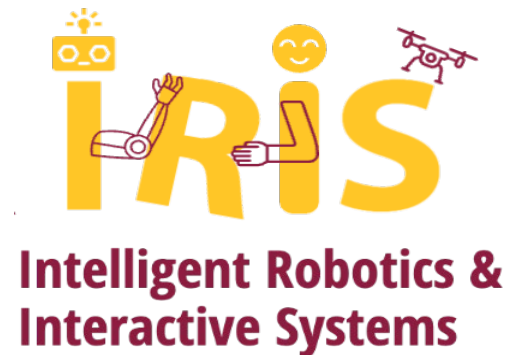
¹University of Texas at Dallas, ²Arizona State University



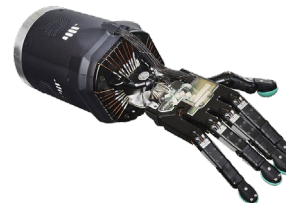
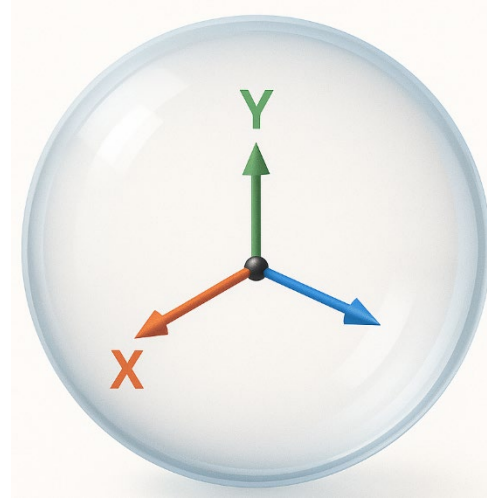
7/13/2026

Workshop on Dexterous Manipulation, RSS 2026

<https://dex-manipulation.github.io/rss2026/>



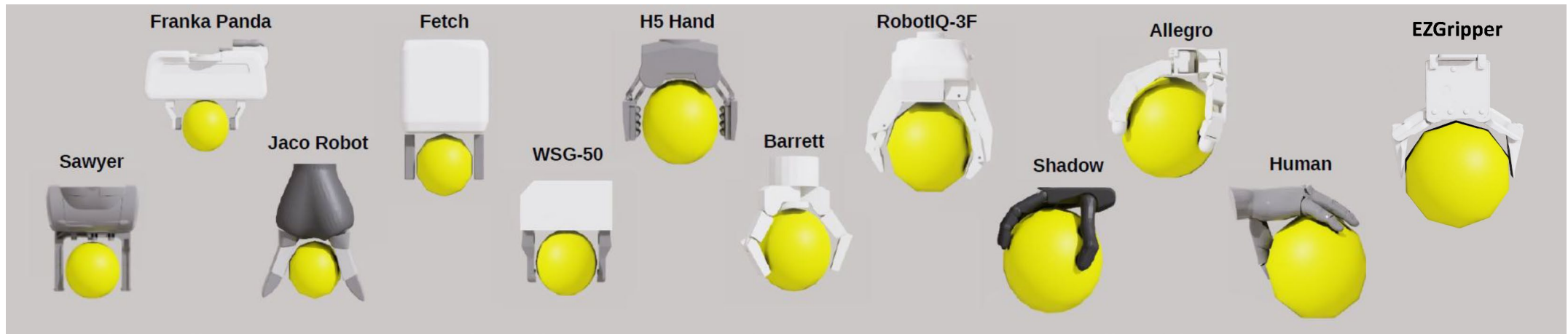
Can we find a unified action space for different robot hands?



Human Hand
(human data)

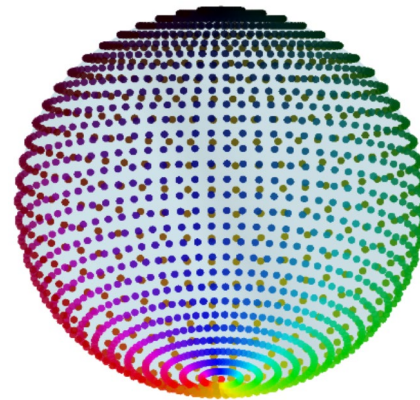
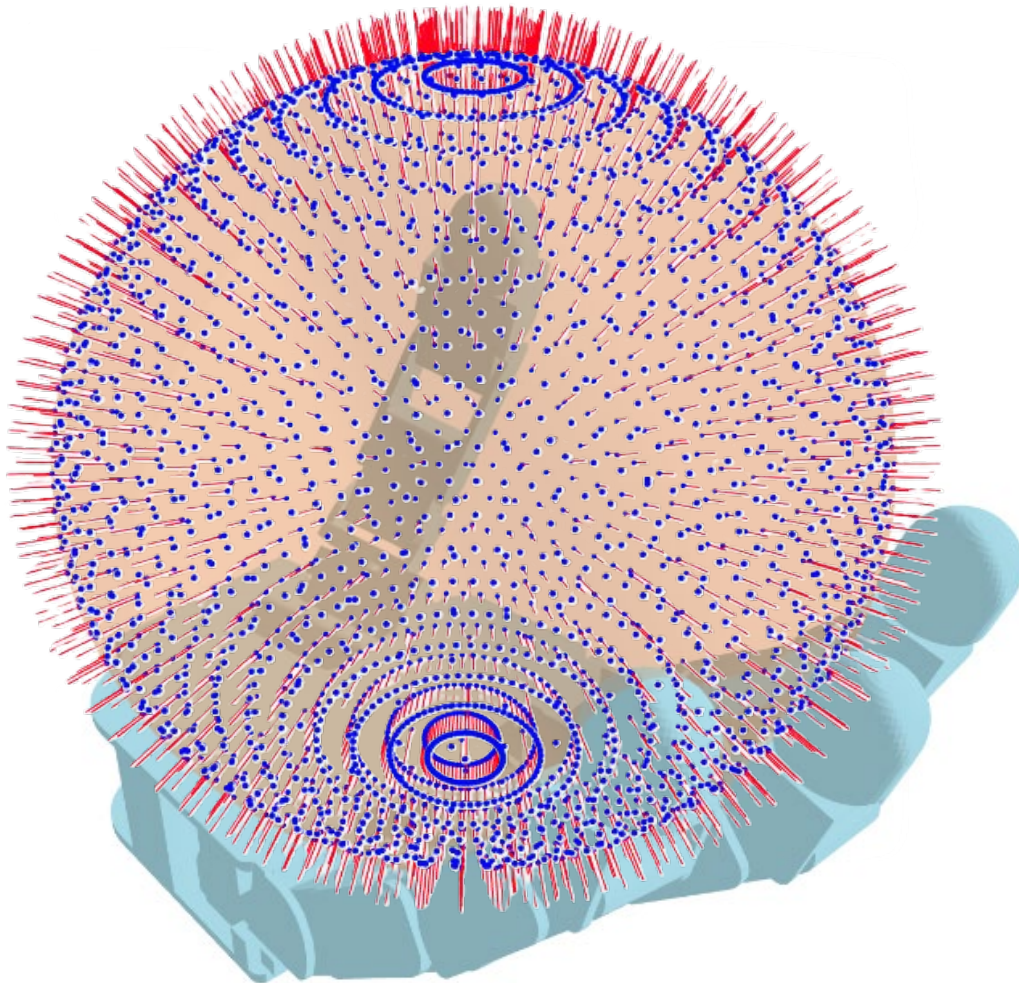
Our idea: Let's use a sphere to align robot hands

- Because any hand can grasp a sphere! (otherwise, it might not be that useful for manipulation)
- Spheres have some good properties for control (you will see)

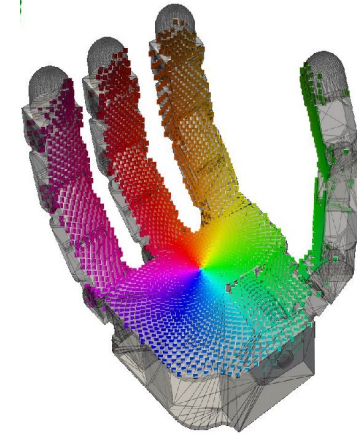


A unified action space for different robot hands

- Map spherical coordinates to the hand

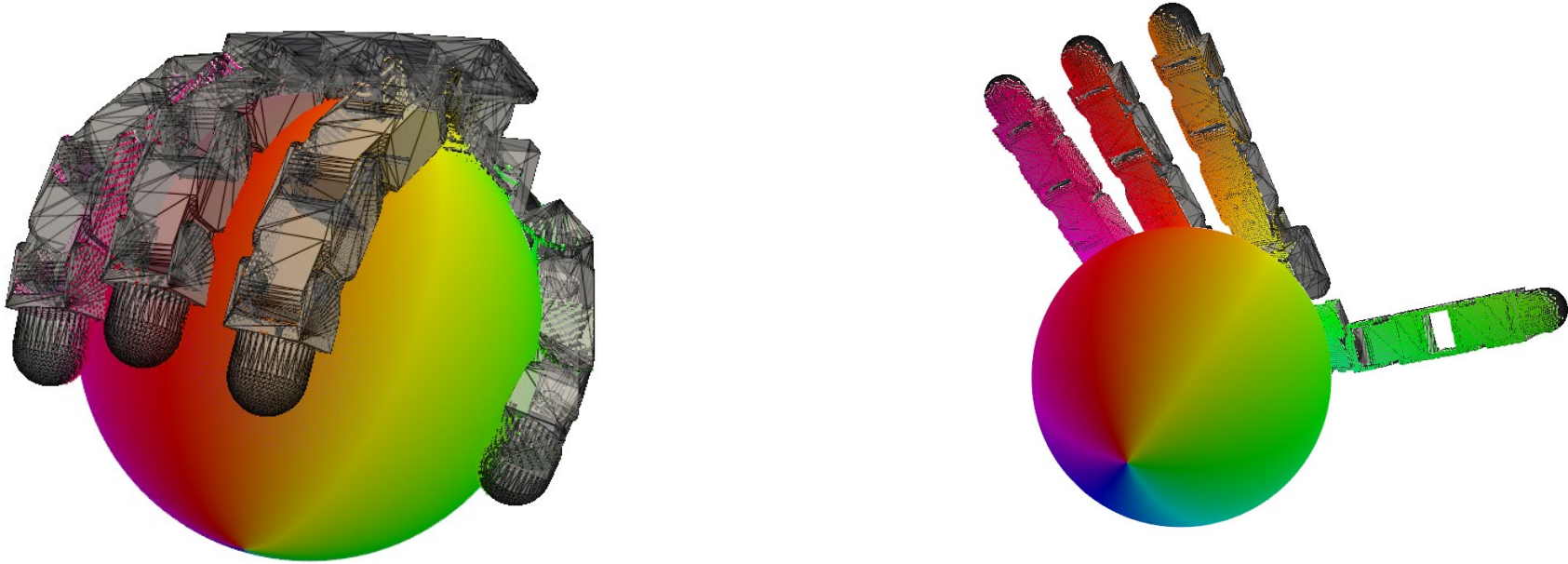


(λ, ϕ)



Transfer the spherical coordinates
to the robotic hand

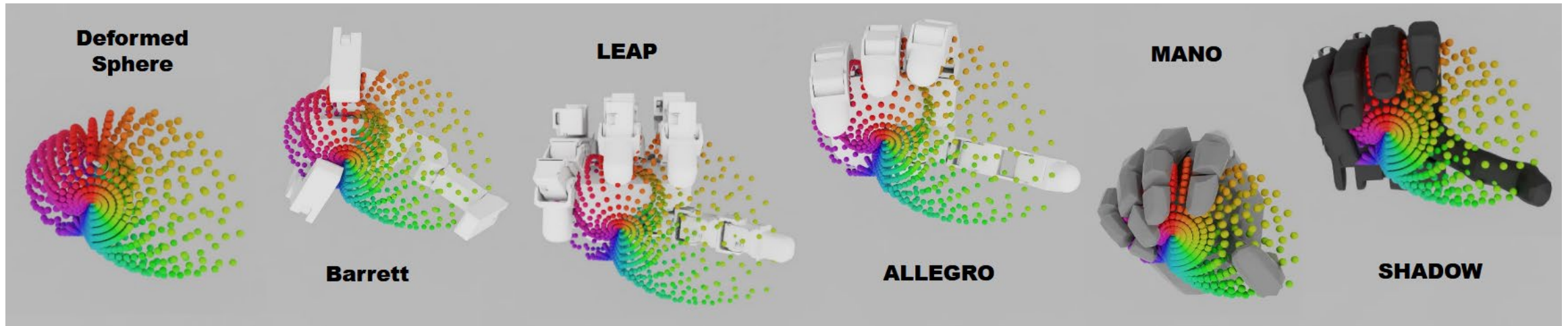
Unified Hand Action Space (UHAS)



Can we use this sphere to control any robotic hand?

Unified Hand Action Space (UHAS)

- **Our Idea:** the deformation of the sphere will drive the movement of the hand (**the hand should touch the deformed sphere correctly**)
- Action space: deformation of the sphere (shared by any hand!)

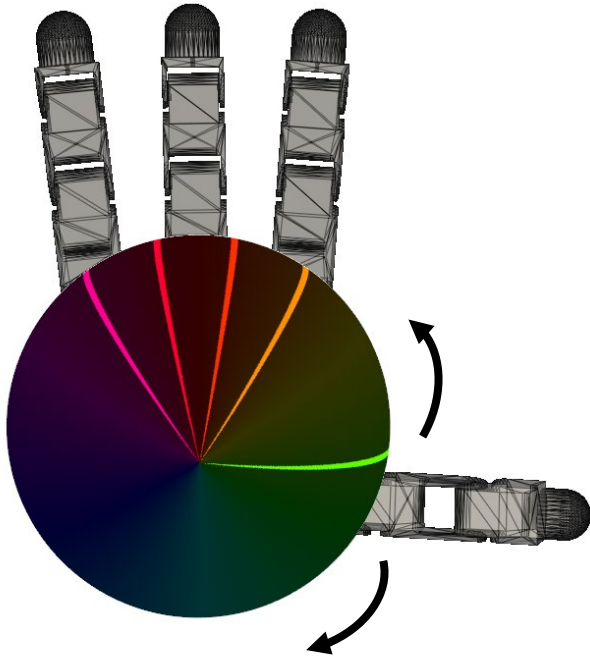


Different hands with the same deformed sphere

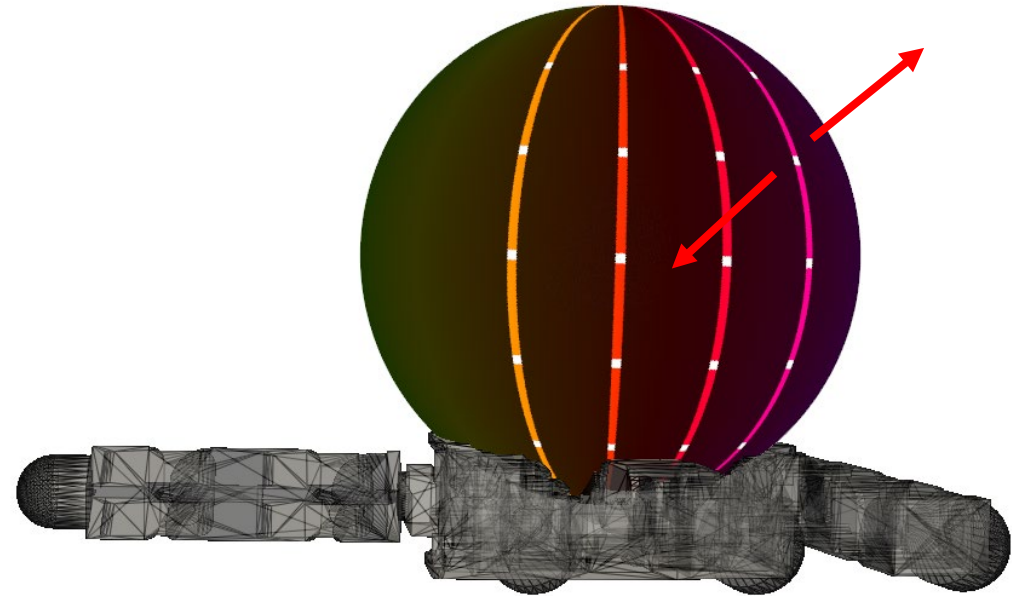
UHAS: deforming the sphere

- Deforming every point on the sphere is too expensive for control

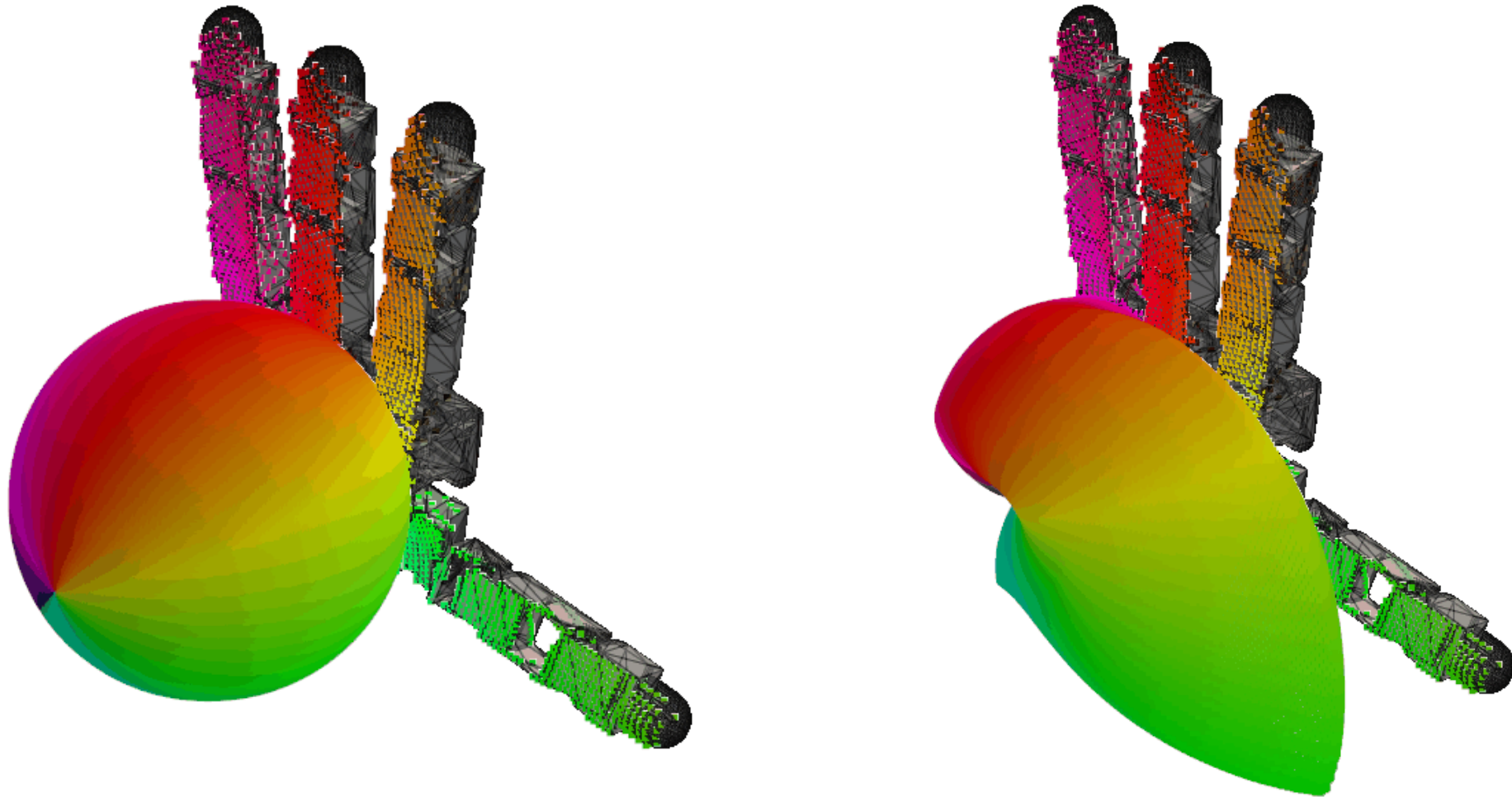
Define several “driving planes”



Define several “driving vectors” on each driving plane

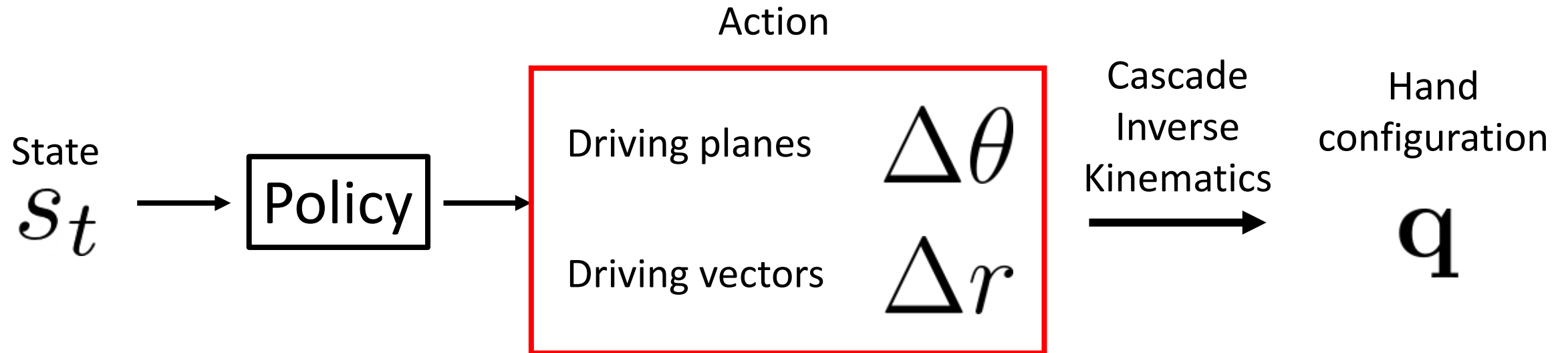
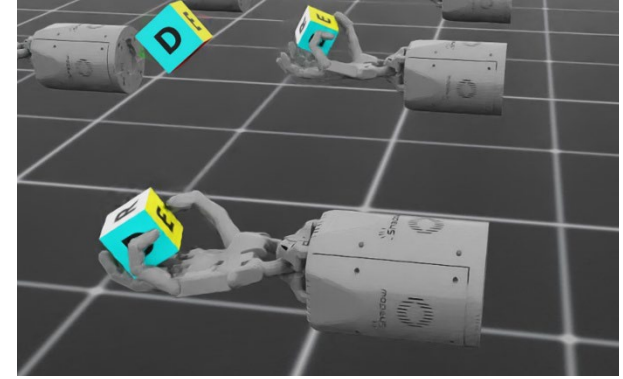


UHAS: Cascade Inverse Kinematics (CIK)



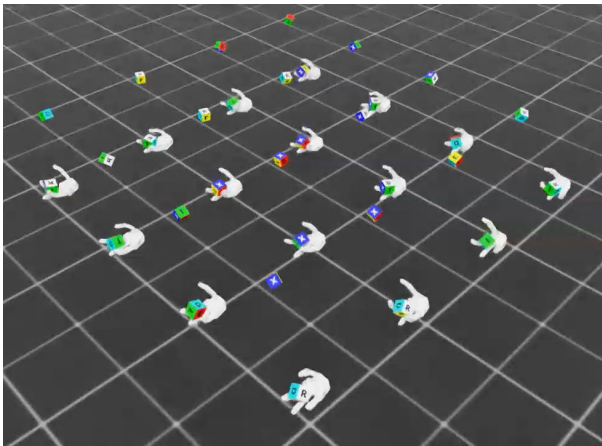
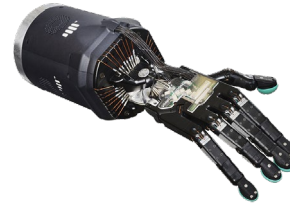
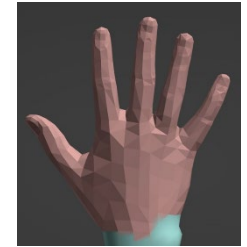
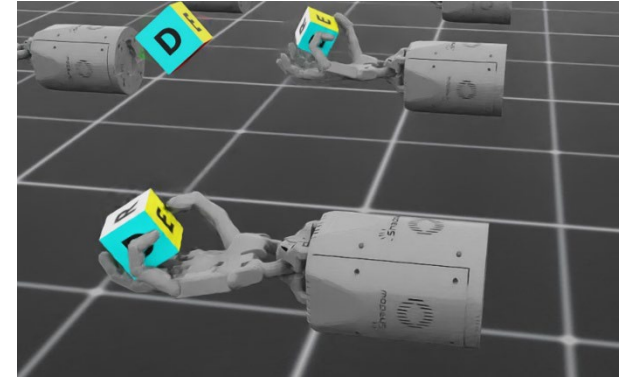
UHAS for In-hand Manipulation

- Task: repose a cube to a target orientation
 - 10 consecutive reposing within 30 seconds
 - RL training in Isaac Lab with PPO and our sphere controller

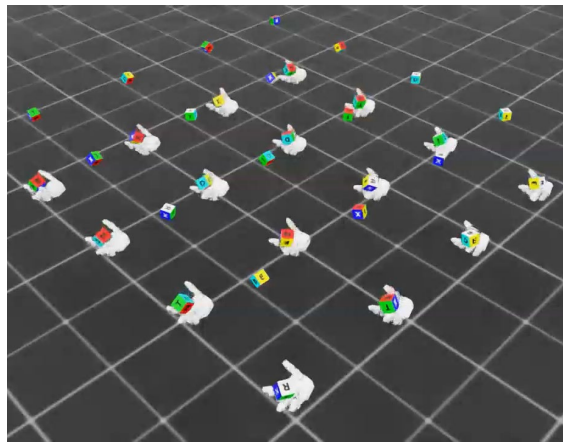


UHAS for In-hand Manipulation

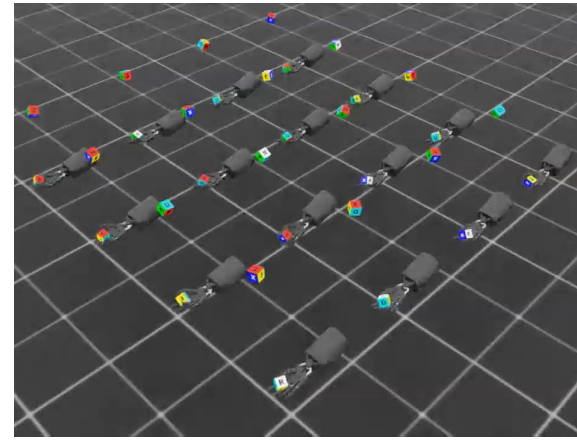
- Task: repose a cube to a target orientation
 - 10 consecutive reposing within 30 seconds
 - RL training in Isaac Lab with PPO and our sphere controller



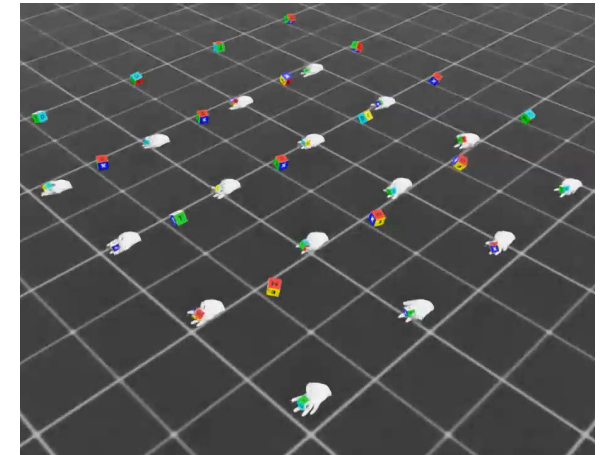
Allegro (4 fingers)
 9.6 ± 1.7



Leap (4 fingers)
 9.8 ± 1.1



Shadow Hand (5 fingers)
 9.6 ± 1.6



MANO human (5 fingers)
 9.9 ± 1.0 10

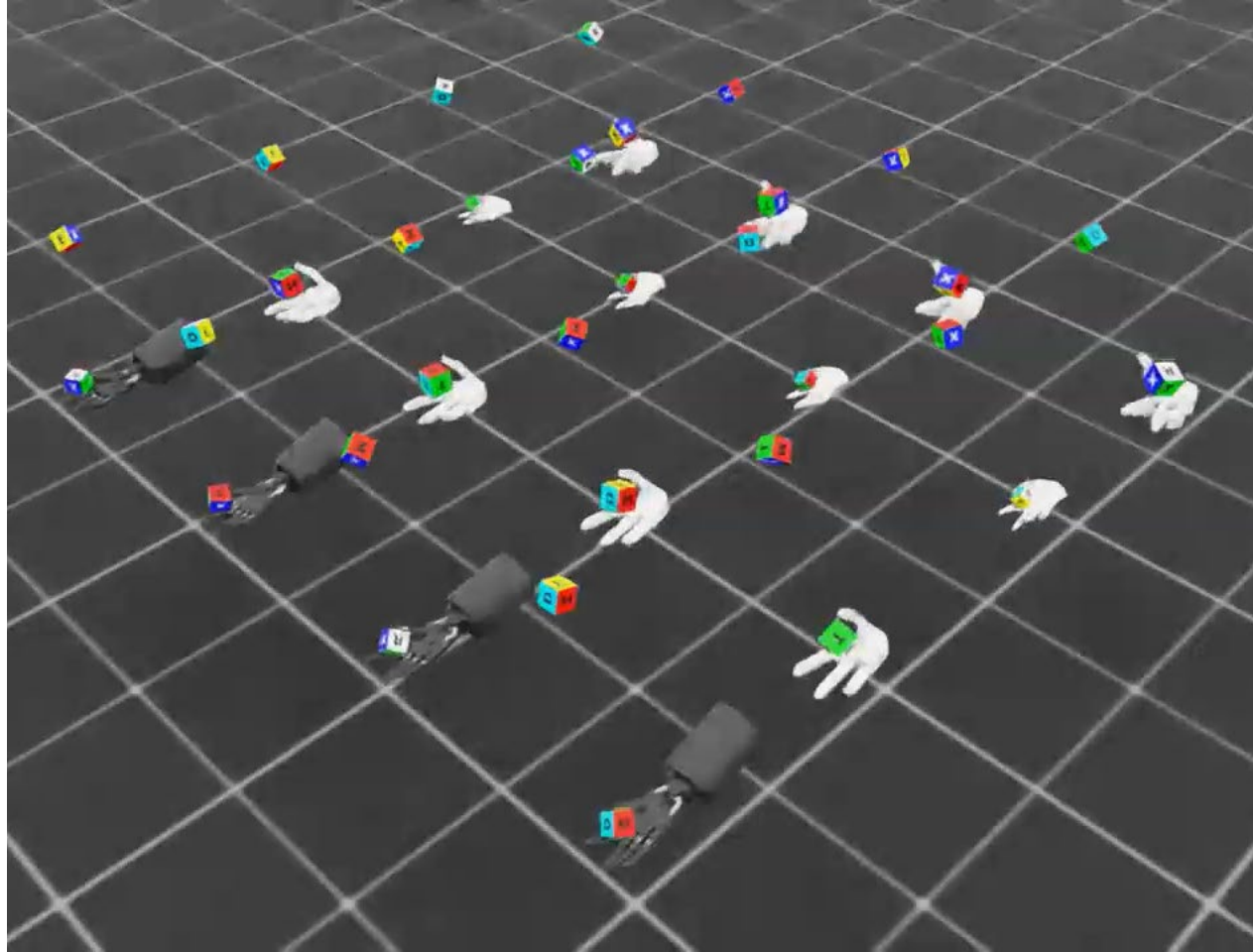
UHAS for In-hand Manipulation



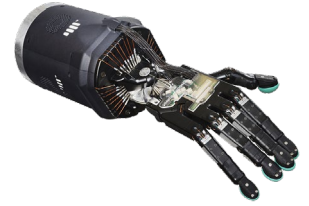
Allegro (4 fingers)
 9.5 ± 1.9



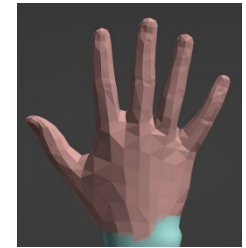
Leap (4 fingers)
 9.5 ± 1.9



Training on all 4 hands



Shadow Hand (5 fingers)
 9.2 ± 2.3



MANO human (5 fingers)
 9.8 ± 1.2

Zero-Shot Policy Transfer (3 In Domain -1 Out of Domain)

Training



Testing

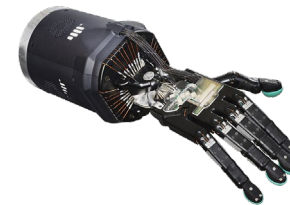
Allegro (4 fingers)
 7.7 ± 3.4



Leap (4 fingers)
 7.7 ± 3.5



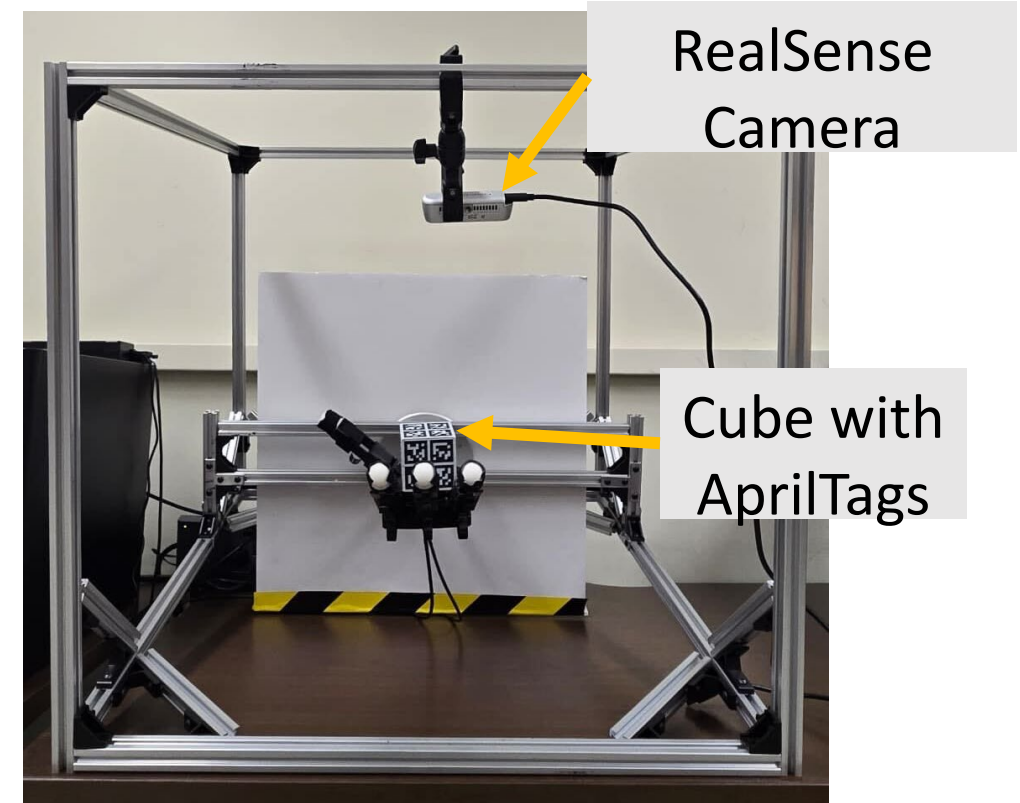
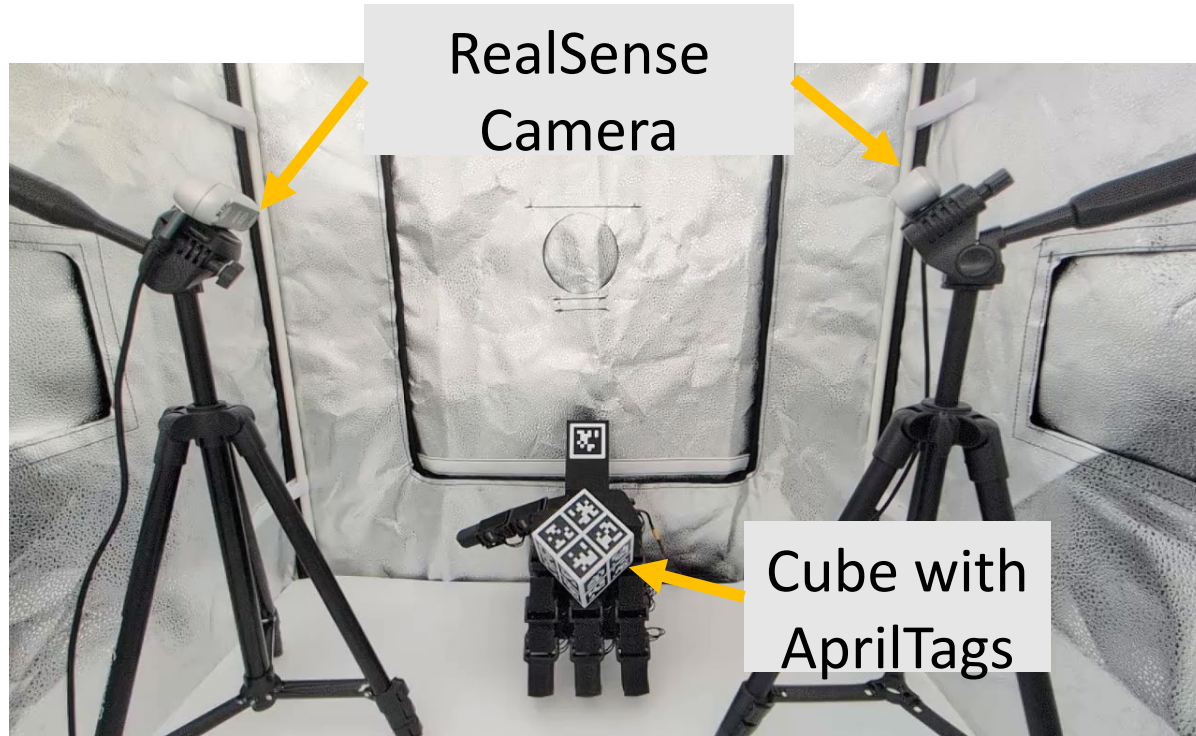
Shadow Hand (5 fingers)
 4.4 ± 3.7



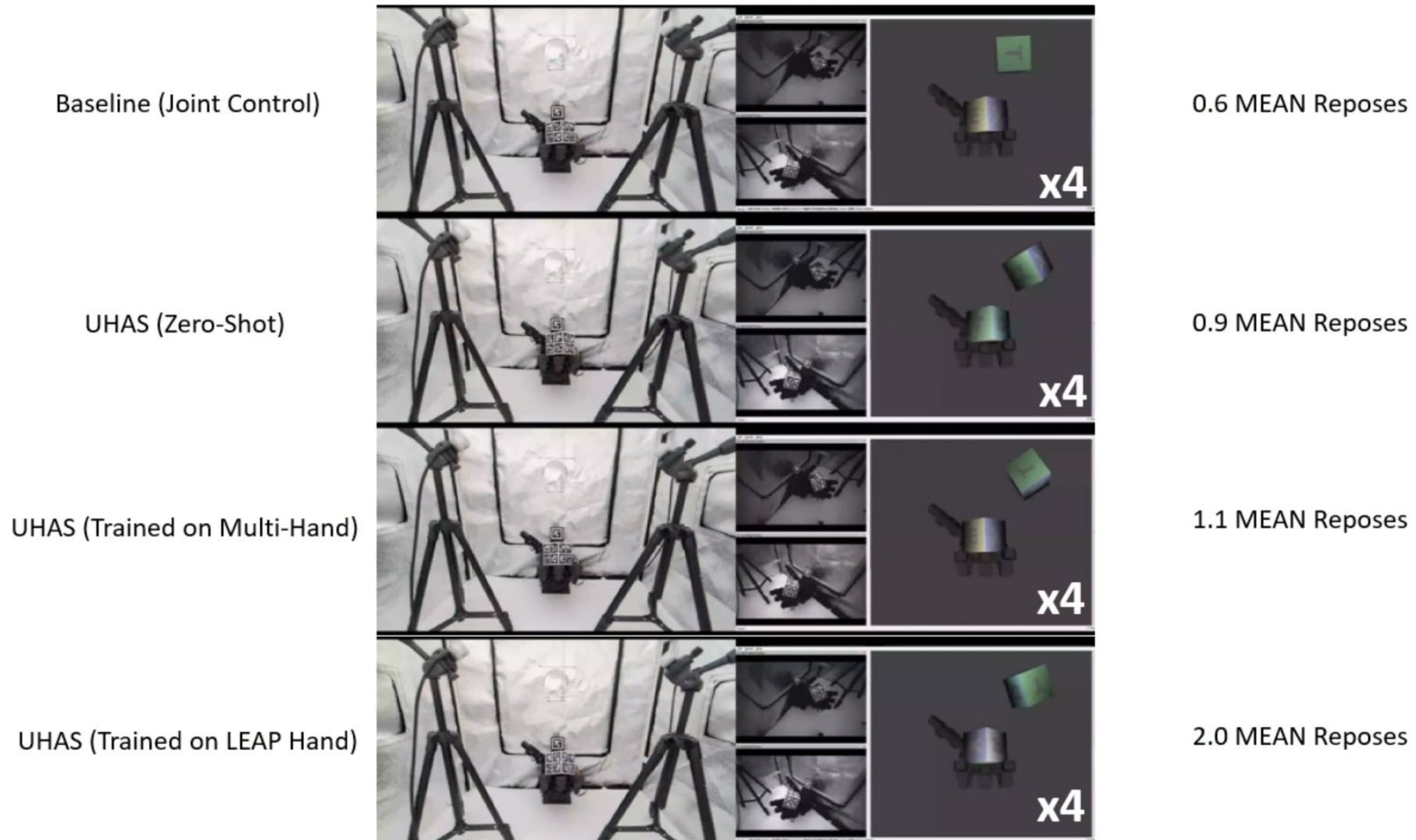
MANO (5 fingers)
 8.9 ± 2.6



Real-world in-hand manipulation

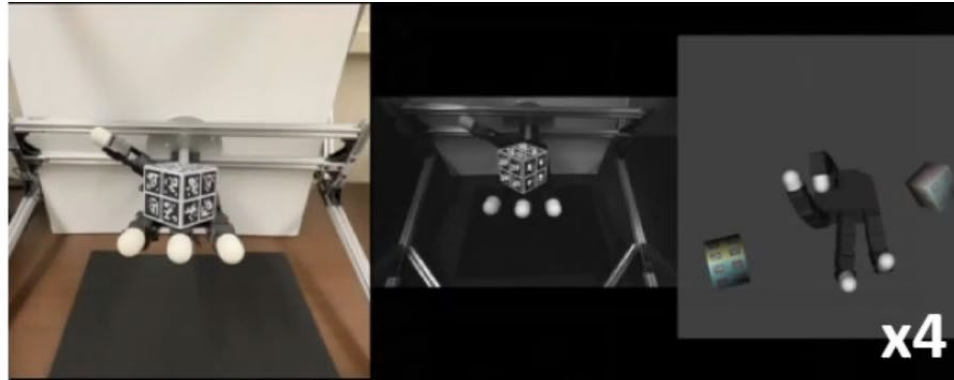


Real-world in-hand manipulation: LEAP hand



Real-world in-hand manipulation: Allegro hand

UHAS (Zero-Shot)



UHAS (Trained on Multi-Hand)

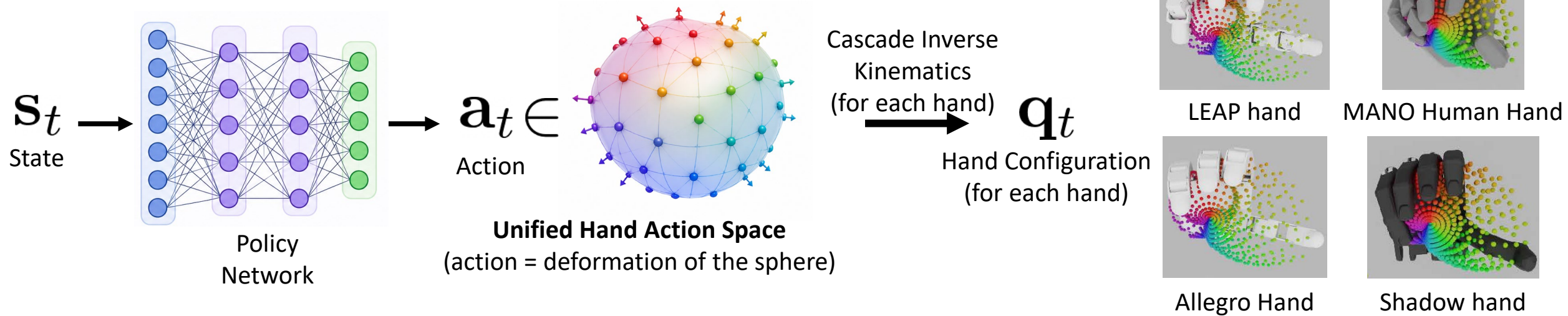


UHAS (Trained on Allegro Hand)



Conclusion

- Unified Hand Action Space for Cross-Embodiment Robot Manipulation



Thank you!