DexRefine: Refine Human Motion to Physically Feasible Robotic Actions

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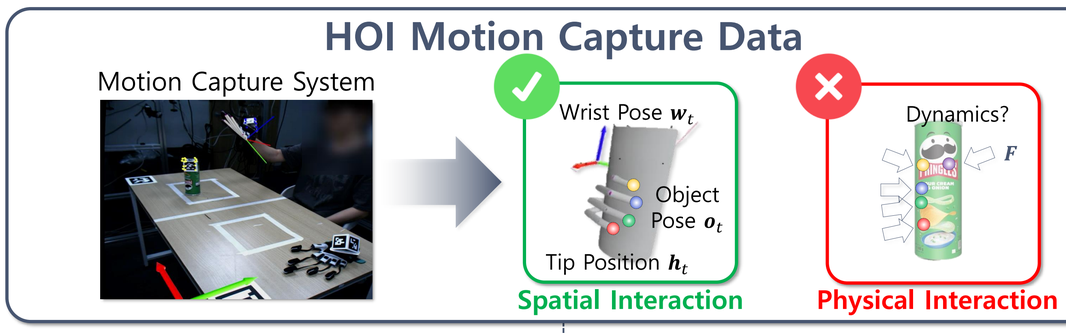
MOTIVATIONS

Motion capture data is a **scalable and accessible** resource for robot motion datasets. However, it suffers from two fundamental limitations: a **lack of physical interaction data** and the inherent **embodiment gap** between humans and robots. Consequently, direct **motion retargeting is often a suboptimal solution**.



METHODS

We propose **DexRefine**, a **task space residual reinforcement learning framework** that **refines human motion into physically feasible robot actions**. Our policy learns **residuals on the wrist and fingertips** to keep the object trajectory aligned with a given reference trajectory.

"Learn Task Space Residual Actions for wrist and finger tips"

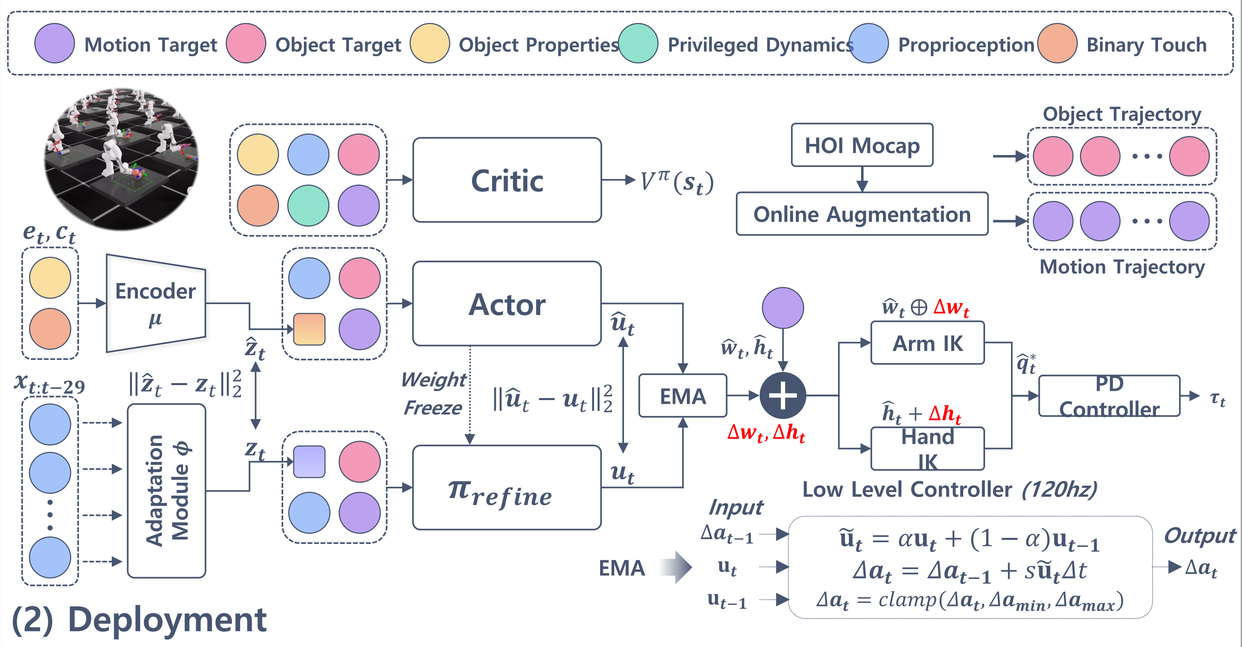
$$\Delta w_t, \Delta h_t = \pi_\theta(s_t)$$
$$\theta^* = \underset{\theta}{argmin}\, J(\theta)$$

RL Main Objective Function

$$J(\theta) = \mathbb{E}_{\tau\sim\pi_\theta}\left[\sum_{t=0}^{T}(\|\hat{o}_t - o_t\|_2 + \|\hat{x}_t - x_t\|_2)\right]$$

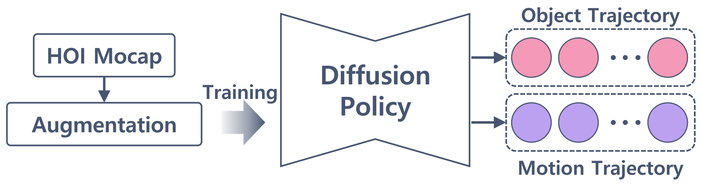
"Ensure Object Trajectory" ($\hat{o}_t$) — "Motion Guidance" ($\hat{x}_t$) + *Additional Objective*: "Floor Collision Avoidance", "Smooth out Jittery Motion"

(1) Train Refinement Policy

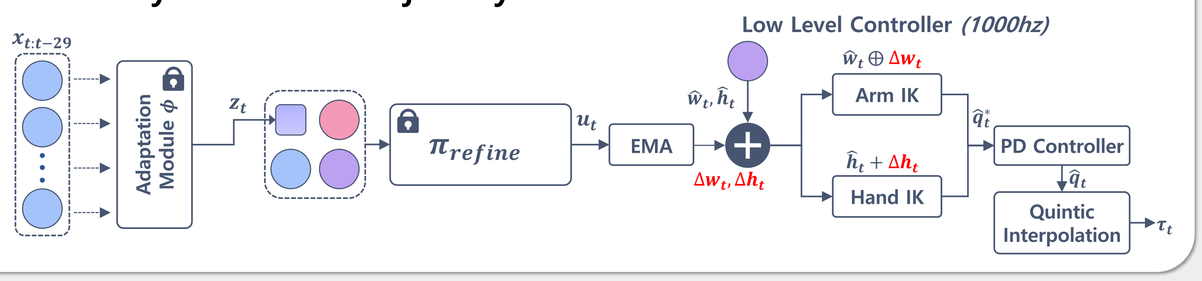


(2) Deployment

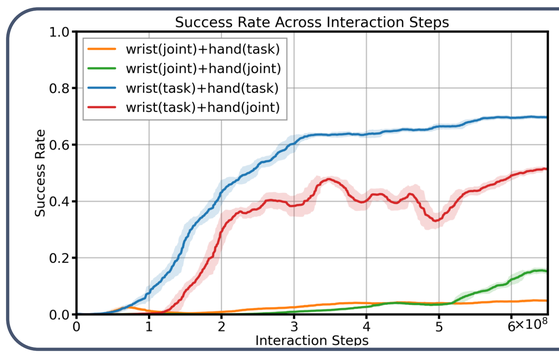
1. Generate **Synthetic HOI Trajectory** conditioned on Object Initial Pose.



2. Refine **Synthetic HOI Trajectory**.



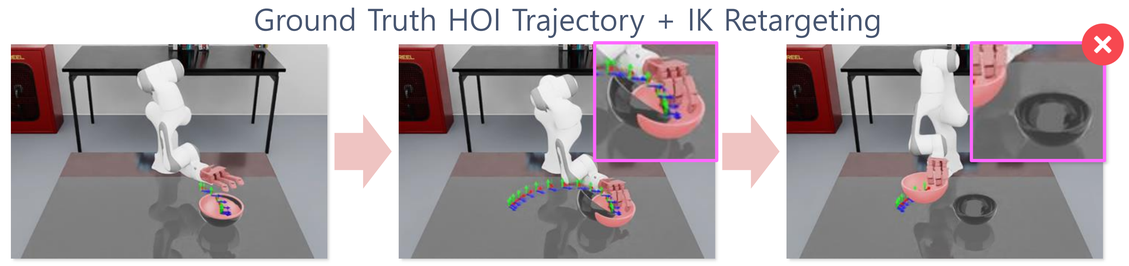
RESULTS



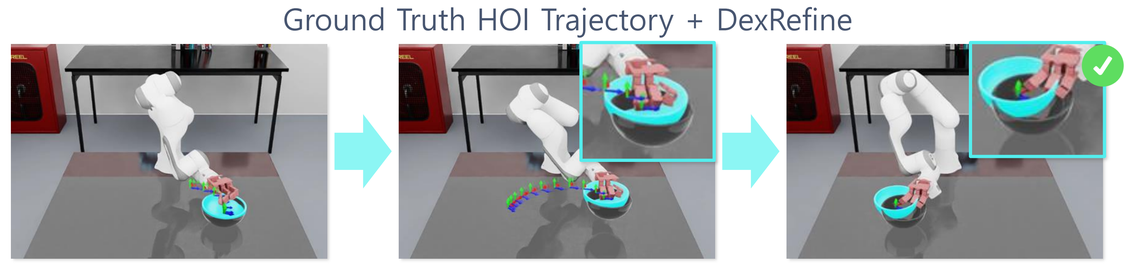
Learning residual actions in task space, particularly for the wrist, is the most critical component for task success.

Task 1: Pick and Place Bowl

Ground Truth HOI Trajectory + IK Retargeting



Ground Truth HOI Trajectory + DexRefine



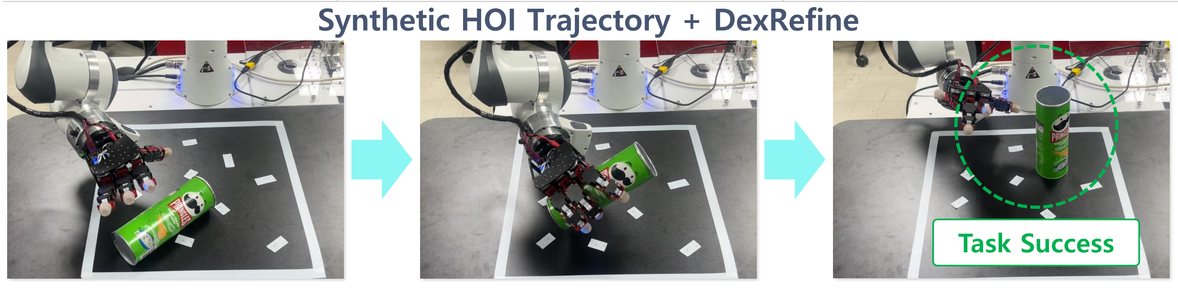
Task 2: Bottle Reorientation

Ground Truth HOI Trajectory + IK Retargeting

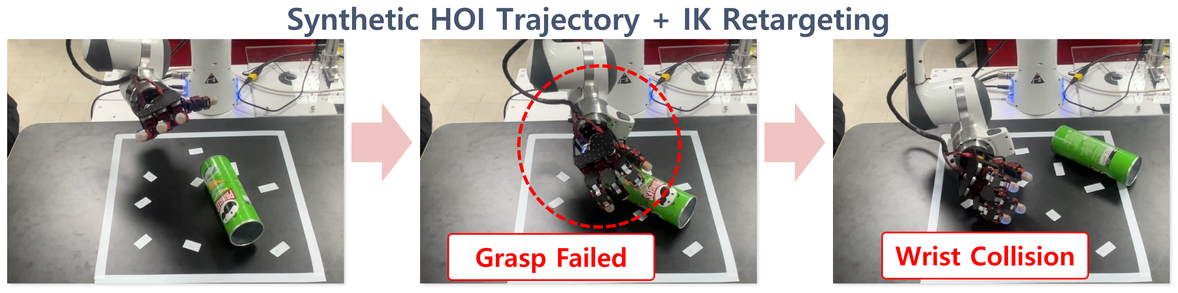
Ground Truth HOI Trajectory + DexRefine

Task / Settings	Reorientation Bottle	Pick and Place bowl
IK based Retargeting	14/105 (12.4%)	20/34 (58.8%)
Ours	**92/105 (87.6%)**	**34/34 (100.0%)**

Synthetic HOI Trajectory + DexRefine



Synthetic HOI Trajectory + IK Retargeting



Method	Success Rate	OTE (m)	OOE (°)
Synthetic HOI + DexRefine (Ours)	**10/10**	**0.015 ± 0.011**	**5.82 ± 6.10**
Synthetic HOI + IK	2/10	0.031 ± 0.046	11.75 ± 18.98

Discussion and Future Works

- We demonstrated that DexRefine, through task-space residual learning, effectively bridges the embodiment gap by **generating behaviors, such as in-hand manipulation, that were not present in the original demonstration data**.
- Our future work will **focus on extending and validating the DexRefine framework across a more diverse range of tasks and objects** to evaluate its generalization capabilities.