APPENDIX

VIII. RL TRAINING CURVES

The RL training curves are shown in Fig. 4. CADRE achieves higher rewards than baselines given the same number of environment interactions. In the screwdriver recovery task, although the baseline methods have eventually converged, they fail to match CADRE's performance. For the hole-on-peg task, although all methods are nearing convergence, CADRE consistently outperforms the baselines.

IX. DOMAIN RANDOMIZATION

Since accurately perceiving fast-moving objects can be challenging in real-world scenarios, catching dynamic objects for recovery needs to handle significant uncertainties. To address this, we apply domain randomization [1] to improve robustness. Specifically, we introduce external disturbances and perception noise: at each time step, a random external wrench $\mathbf{w}_{ext}$ is applied at the center of the screwdriver, and random perception noise $\boldsymbol{\epsilon}$ sampled from a uniform distribution is added to the object's pose and velocities.

X. PARAMETERS FOR GENERATING OBJECTS

For OOD object design, we specifically choose shorter screwdrivers and thinner sockets as those choices present significant challenges, where the desired contact regions are smaller and generally require more precise finger control.

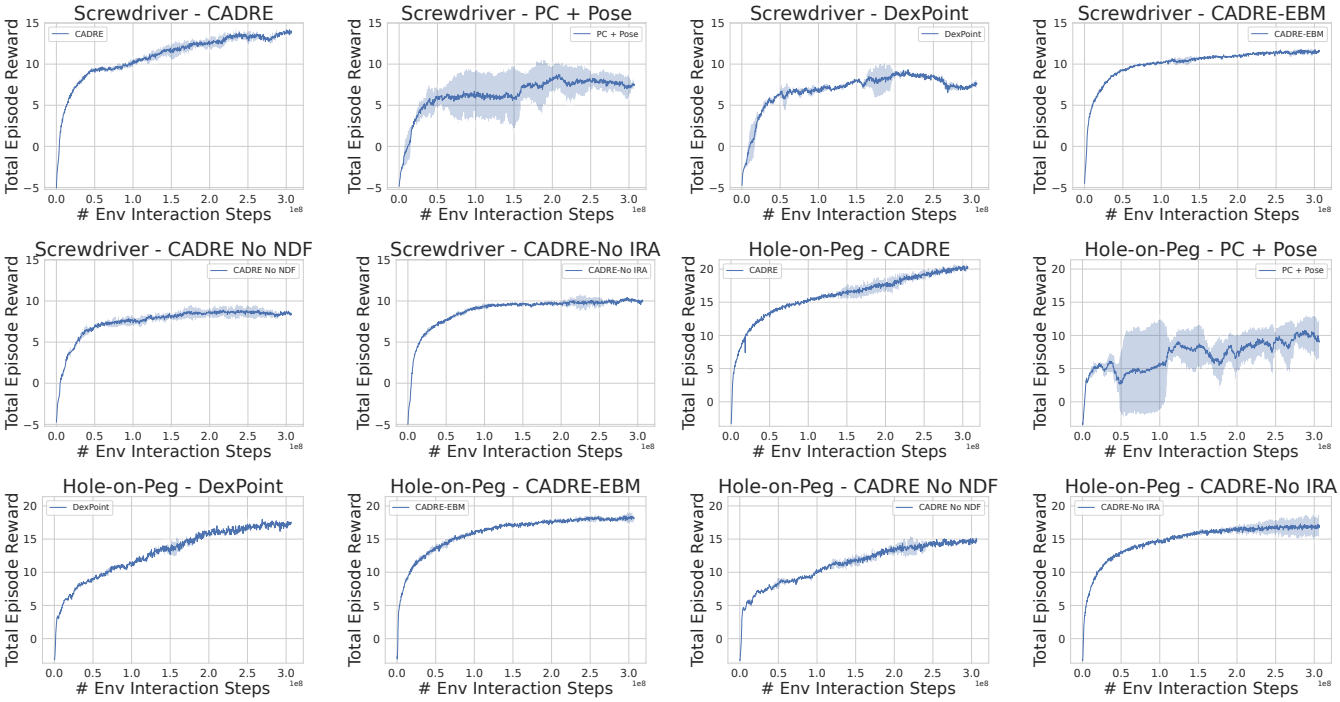

Fig. 4: Three different seeds are used for RL training, and the average results are shown. The variance is relatively small as we use a large batch size during training.

	Screwdriver				Socket		
	handle r	handle l	shaft r	shaft l	inner r	outer r	thickness
ID	$\mathcal{U}(1,3)$	$\mathcal{U}(7,14)$	$\mathcal{U}(0.4,1.4)$	$\mathcal{U}(8,10)$	$\mathcal{U}(1,2.5)$	$\mathcal{U}(3,4)$	$\mathcal{U}(3,5)$
OOD	$\mathcal{U}(1.5,3)$	$\mathcal{U}(2,4)$	$\mathcal{U}(0.3,0.7)$	$\mathcal{U}(2,4)$	$\mathcal{U}(1,2.5)$	$\mathcal{U}(3,4)$	$\mathcal{U}(1,3)$

TABLE IV: Distribution used for generating object geometries. r: radius, l: length. $\mathcal{U}$ means uniform distribution. All units are in centimeters. OOD objects are generally shorter(screwdriver) or thinner(socket) than ID ones.