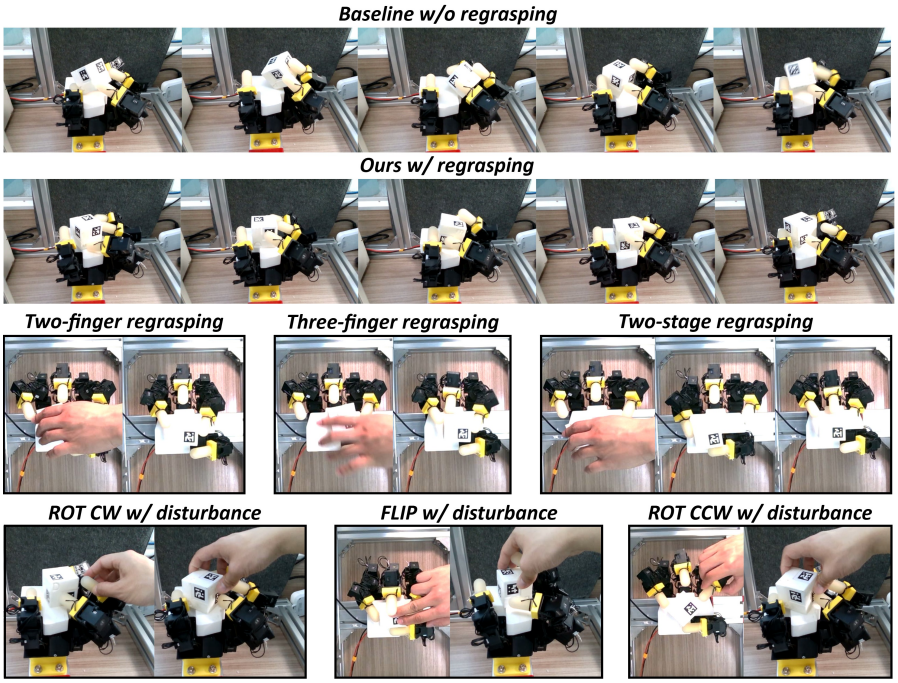

Fig. 1: Snapshots of the video attachment. Videos recorded from two perspectives (i.e., top, side) are provided.

APPENDIX

A. Video Attachment

Experimental results and comparisons are shown in the attached video and the snapshots in Fig. 1, including:

- **The complete cube reorientation task:** The baseline shows aggressive behavior and a lower success rate when deploying the RL policies. This is because the cube is often not centered, resulting in out-of-distribution (OOD) data where the fingers fail to form a firm grasp. Whereas our framework achieves robust performance through intermittent regrasping.
- **The regrasping unit test:** We manually reset the position of the cube and perform the regrasping. Combinations of different fingers are involved when the cube is located at different parts of the palm. A two-stage strategy is demonstrated to grasp objects on the boundary of the fingers' reachable space.
- **The deployment of RL policies:** The robustness against disturbances is shown when deploying RL policies.

B. Hardware Design

The hardware design is shown in Fig. 2. We customize the LEAP Hand [33] by replacing the official fingertips with 3d-printed bones and silicone sleeves. To obtain the transformation of the camera, we attach one AprilTag to the index finger and calibrate with the *easy_handeye* ROS package.

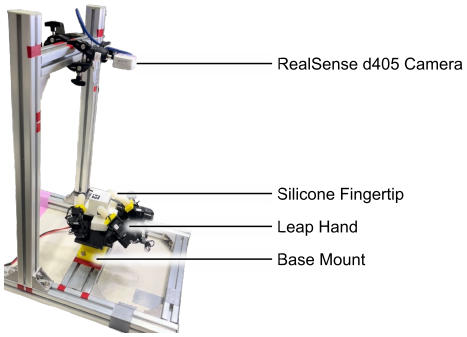

Fig. 2: Hardware Design of Our In-Hand Manipulation System

C. Software Stack

In the supplementary code, we include the customized hand's CAD files, the deployment code of low-level RL policies, and the high-level perception and decision module as ROS packages. The communication between the high level and the low level is implemented through ROS Action. Besides, we also provide the Isaac Gym simulation environment for training the RL policies with the domain randomization parameters listed in Tab. I. The weights of each reward term are listed in Tab. II. We keep the parameters of the PPO agent the same as the RL examples of LEAP Hand [33].

TABLE I: Randomization parameters

property	range
object mass	$[0.01, 0.09]$kg
object COM location	$[0.01, 0.01]^3$m^3
object scale	$\{0.9, 0.95, 1.0, 1.05, 1.1\}$
friction of fingertip	$[0.8, 2.0]$
friction of other parts	$[0.1, 0.6]$
actuator P gain	$[2.9, 3.1]$
actuator D gain	$[0.09, 0.11]$

TABLE II: Weights of reward terms (ROT, FLIP)

reward	weight	reward	weight
r_{angvel}	(1.25,1.25)	r_{dof}	(-0.2,-0.025)
r_{linvel}	(-0.3,N/A)	r_{ftip}	(N/A,-3)
r_{energy}	(-1,-1)	r_{contact}	(N/A,0.5)
r_{torque}	(-0.1,-1.0)	r_{goal}	(N/A,1.0)