Paper arXiv Video Code

DoorBot

Closed-Loop Task Planning and Manipulation for Door Opening in the Wild with Haptic Feedback

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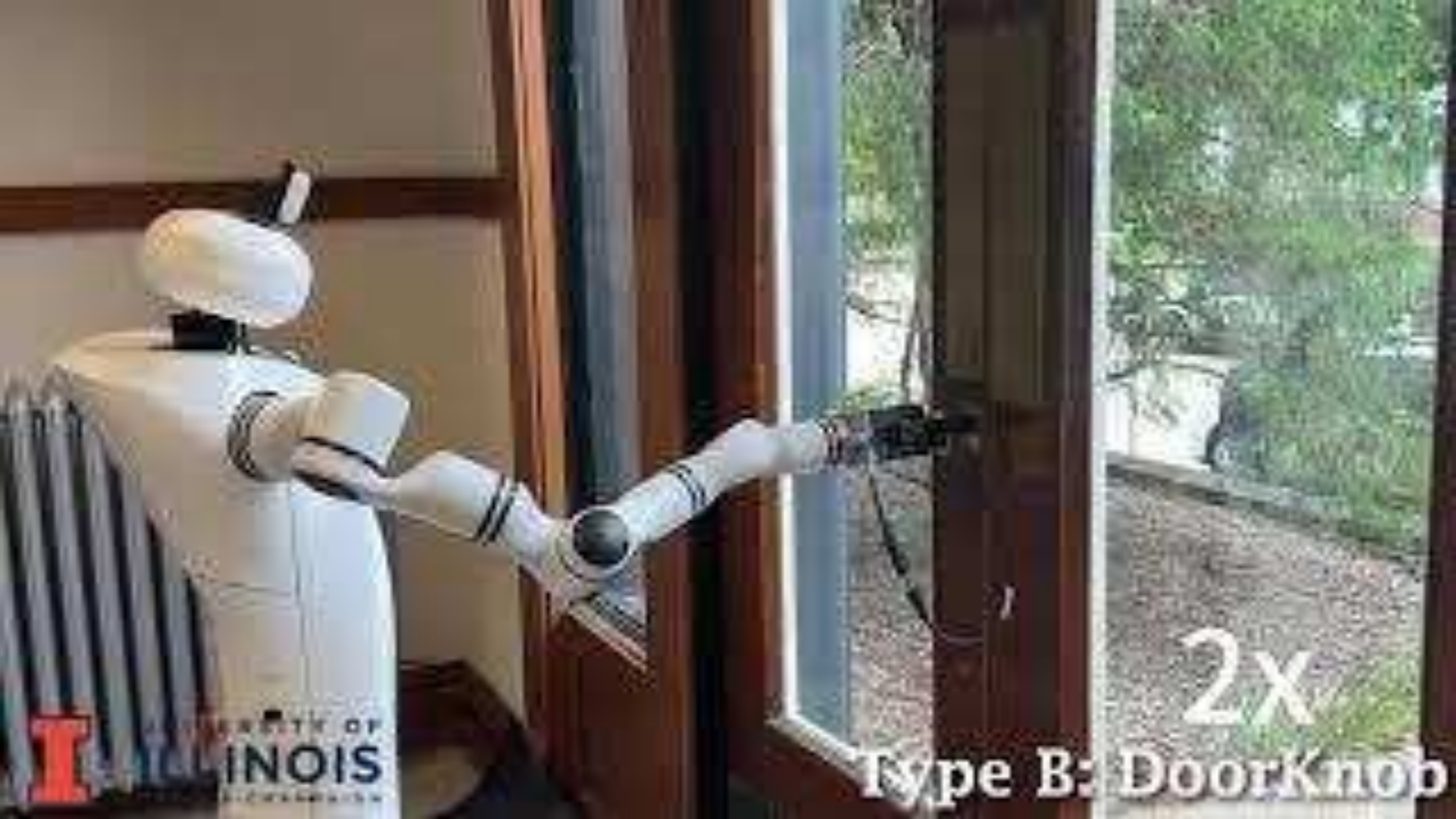

2x
Type B: DoorKnob

Task - Door Opening System

Goal: Develop a system for **unseen doors opening** in **unstructured, real-world environment**.

Features

Dofs	7x2 (arms) + 2 (base) + 2 (head)
Weight	80kg
Size	53L * 209W * 152H
Payload	5kg (per arm), 60kg (base)
Arm Repeatability	0.05mm
Battery Life	11 hours

Components

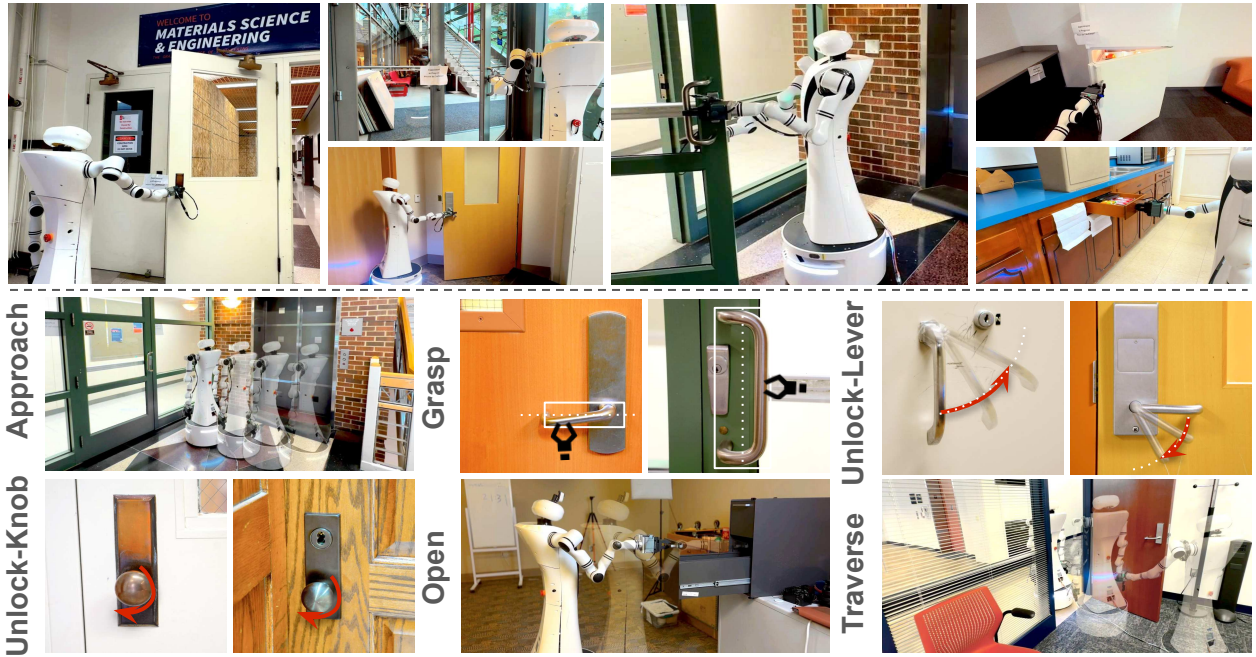
Arms	2 x Real Man RM75-B
Mobile Base	Yunji Water2
Camera	Intel Realsense D435
Grippers	2 x DH PGI-140-80
Head	2 x LX-224HV

Visual Appearance of Our Bimanual and Mobile Robot

Diverse Articulated Objects

Method - Primitives Design

Challenge: **Generalization** (diverse **designs**, **mechanisms**, and **conditions** of articulated objects)



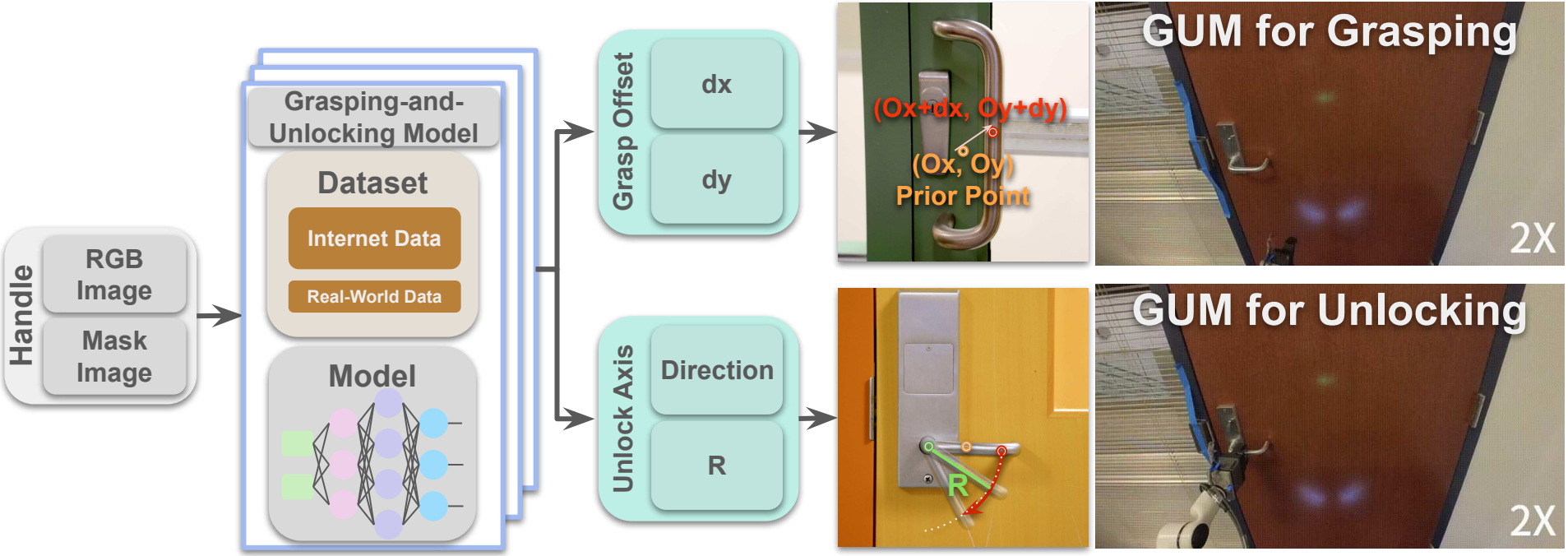
Six Motion Primitives

Primitives: Design **6 primitives** with **parameterized actions**, reducing the **dimensionality of action space**.

Split the task into **High-Level Planner** and **Low-Level Policy.**

Method - Grasping-and-Unlocking Model (GUM)

Novel Representation: **Representation learning** via mapping **2D RGB image** to **3D action parameters**.



Overview of GUM

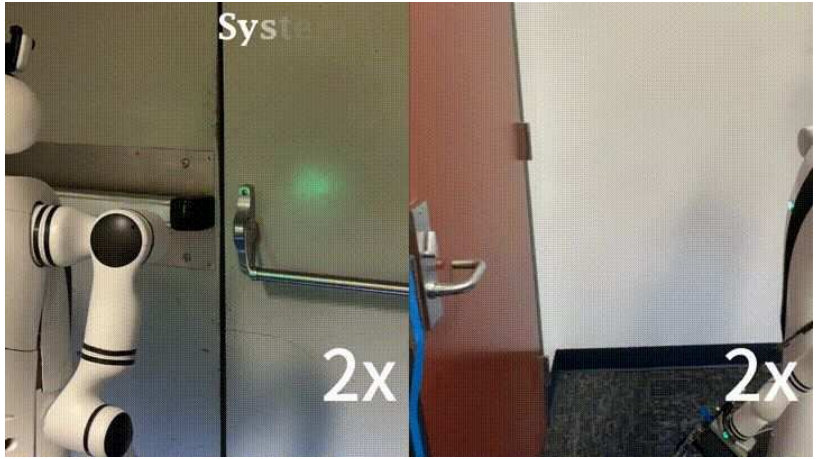
Dataset: **Small** but **Effective**: **1303 data** from Internet and real-world.

Generalization: **Unify** almost all kinds of doors **by One Model**.

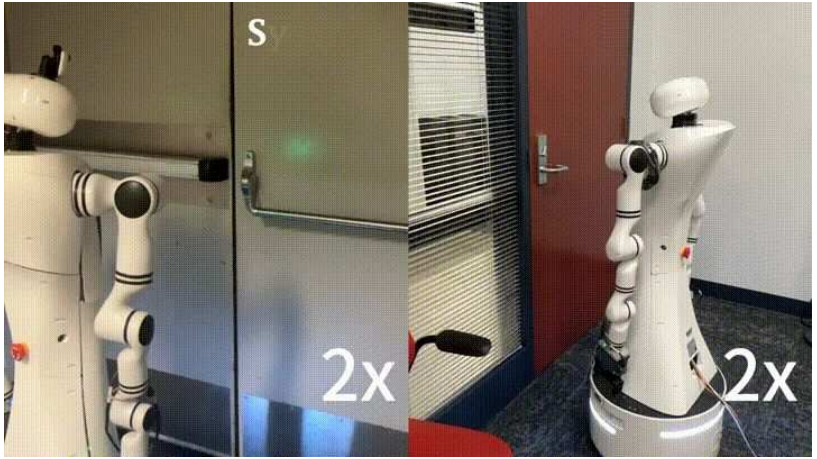
Method - Grasping-and-Unlocking Model (GUM)

Method	Door1	Door2	Door3	Door4	Door5	Avg
w/o GUM	0/5	2/5	3/5	0/5	0/5	***20%***
GUM* (w/o real-world data)	4/5	5/5	5/5	5/5	5/5	***92%***
Ours, GUM (w/ real-world data)	5/5	5/5	5/5	5/5	5/5	***100%***

Table. Effectiveness of GUM.



Inaccurate Depth Estimation
Wrong Unlocking Direction / Trajectory
Bad Generalization of Unusual Shape



Accurate Grasping Offset
Correct Unlocking Axis
Great Generalization Ability

Method - Closed System with Haptic Feedback

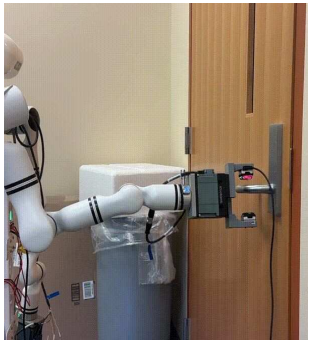
Question: Is Vision Enough?

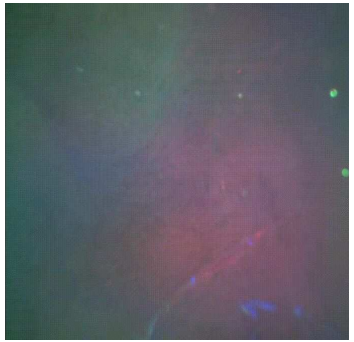
Method	Grasp	Unlock-L	Unlock-K	Open	Push/Pull
CLIP	42.67%	33.33%	38.81%	15.79%	15.00%
Gemini	29.63%	93.75%	86.36%	88.89%	65.00%
Haptics	**100%**	**100%**	**100%**	**100%**	**100%**

Table. VLM VS. HAPTIC.

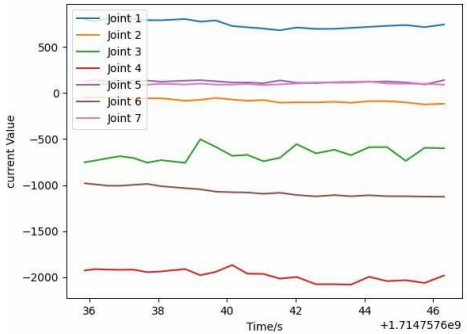
Haptic Feedback for Closed-Loop System:

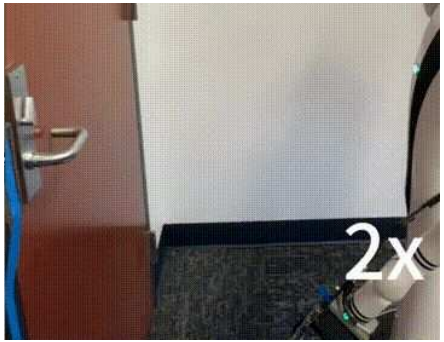
Gelsight Mini (Vision-based tactile sensor)
Useful but Fragile, easy to break





Raw joint current & gripper resistance
Low-cost, Easy-to-implement

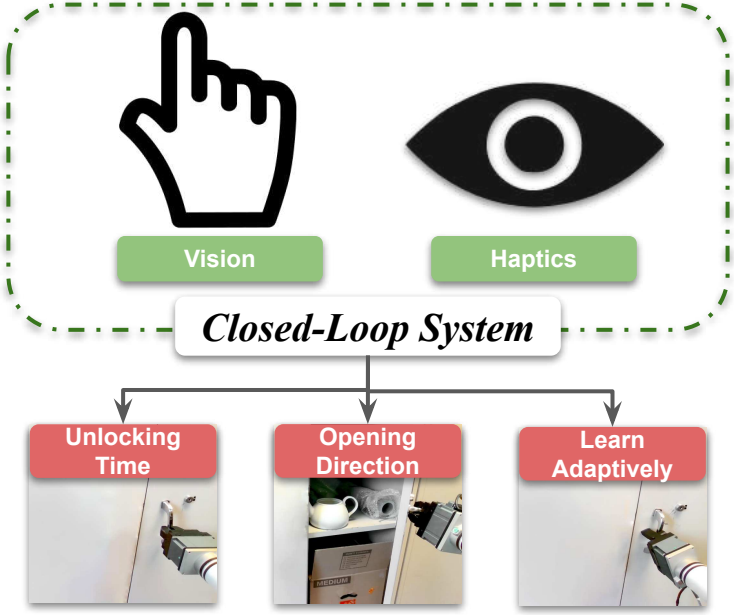




Method - Closed System with Haptic Feedback

Method	door1	door2	door2	door4	door5	Avg
Open-Loop Manner	3/5	1/5	2/5	1/5	3/5	***40%***
Closed-Loop Manner	5/5	5/5	5/5	5/5	5/5	***100%***

Table. Open VS. Closed Loop



Our Closed-Loop System with Haptic Feedback

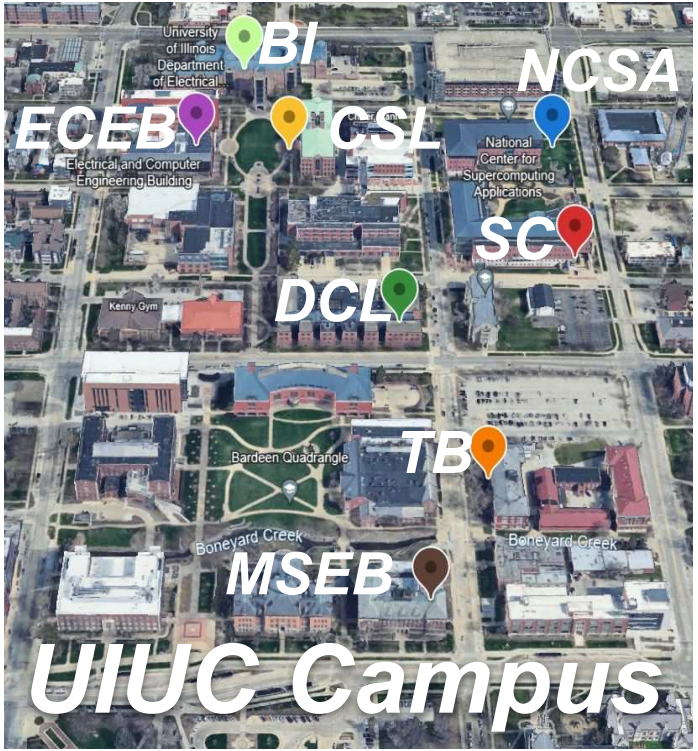
Open-Loop Manner VS. Closed-Loop Manner

Inaccurate Unlocking Time
Wrong Opening Direction
Can't Correct Itself

Accurate Unlocking Time
Correct Opening Direction
Adaptively Learn

Experiments in UIUC Campus

8 buildings, **20 doors, 4 types**, 5 trials, 100 trajectories



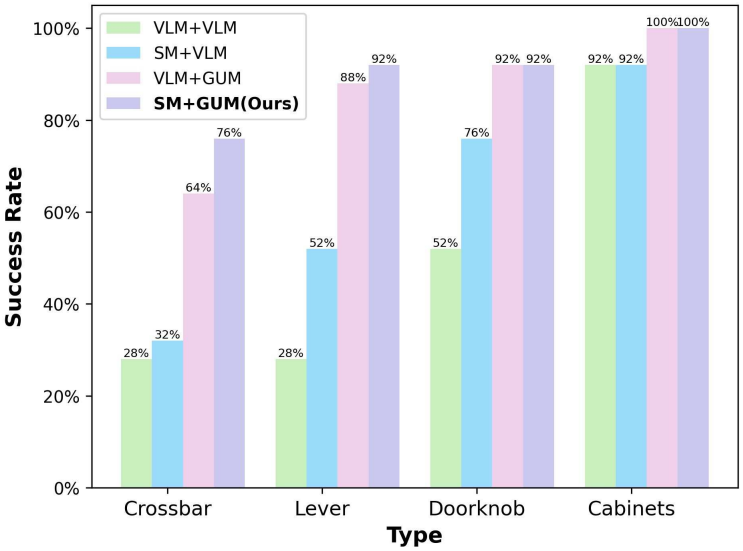
UIUC Campus

Field test setting

Experiments in UIUC Campus

Method		Lever	Doorknob	Crossbar	Cabinets	Sum
High-Level	Low-Level					
VLM	VLM	7/25	13/25	7/25	23/25	***50%***
Ours	VLM	7/25	19/25	8/25	23/25	***57%***
VLM	Ours	22/25	23/25	16/25	25/25	***86%***
Ours	Ours	23/25	23/25	19/25	25/25	***90%***

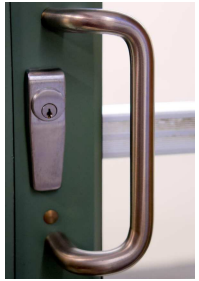
Table. Main Result

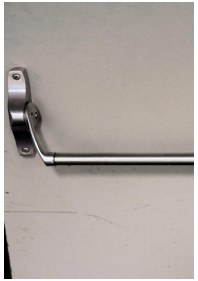


Main Result

Generalization:

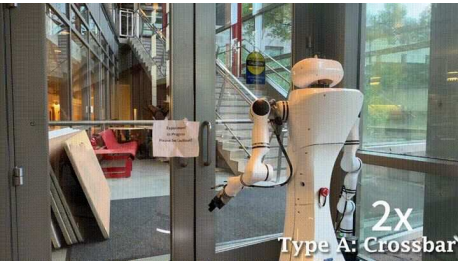
- **Door Types:** push, pull, righ, left
- **Handle Types:** round, curved, big, tiny
- **Appearances:** color, texture
- **Physical Properties:** heavy, light
- **Visual Distractions:** illumination, darkness

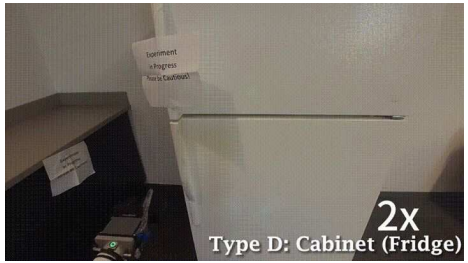




Videos

Four Types of Doors

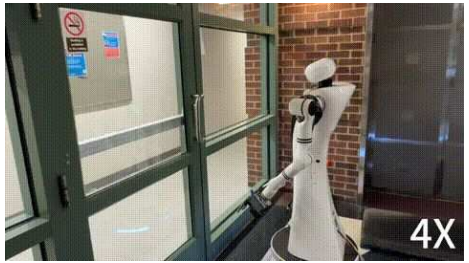




Generalization Ability

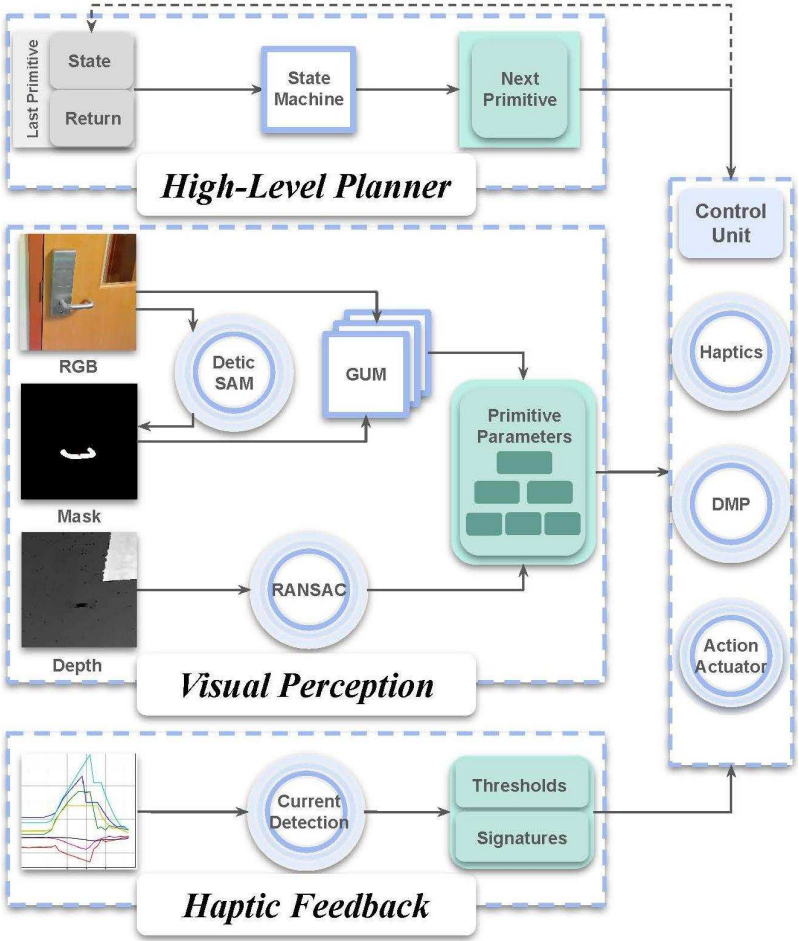
Push and Pull Doors

Manipulation for Door Traversal

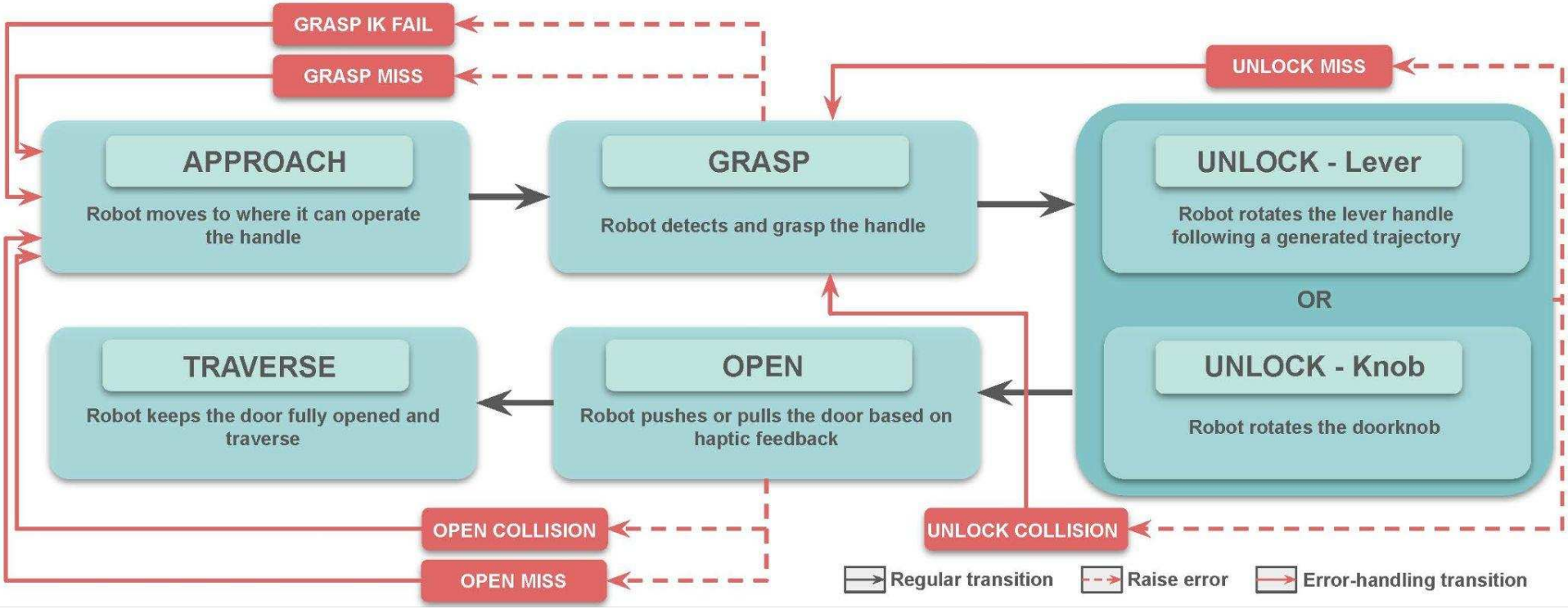


More Videos: https://tx-leo.github.io/DoorBot/#Videos

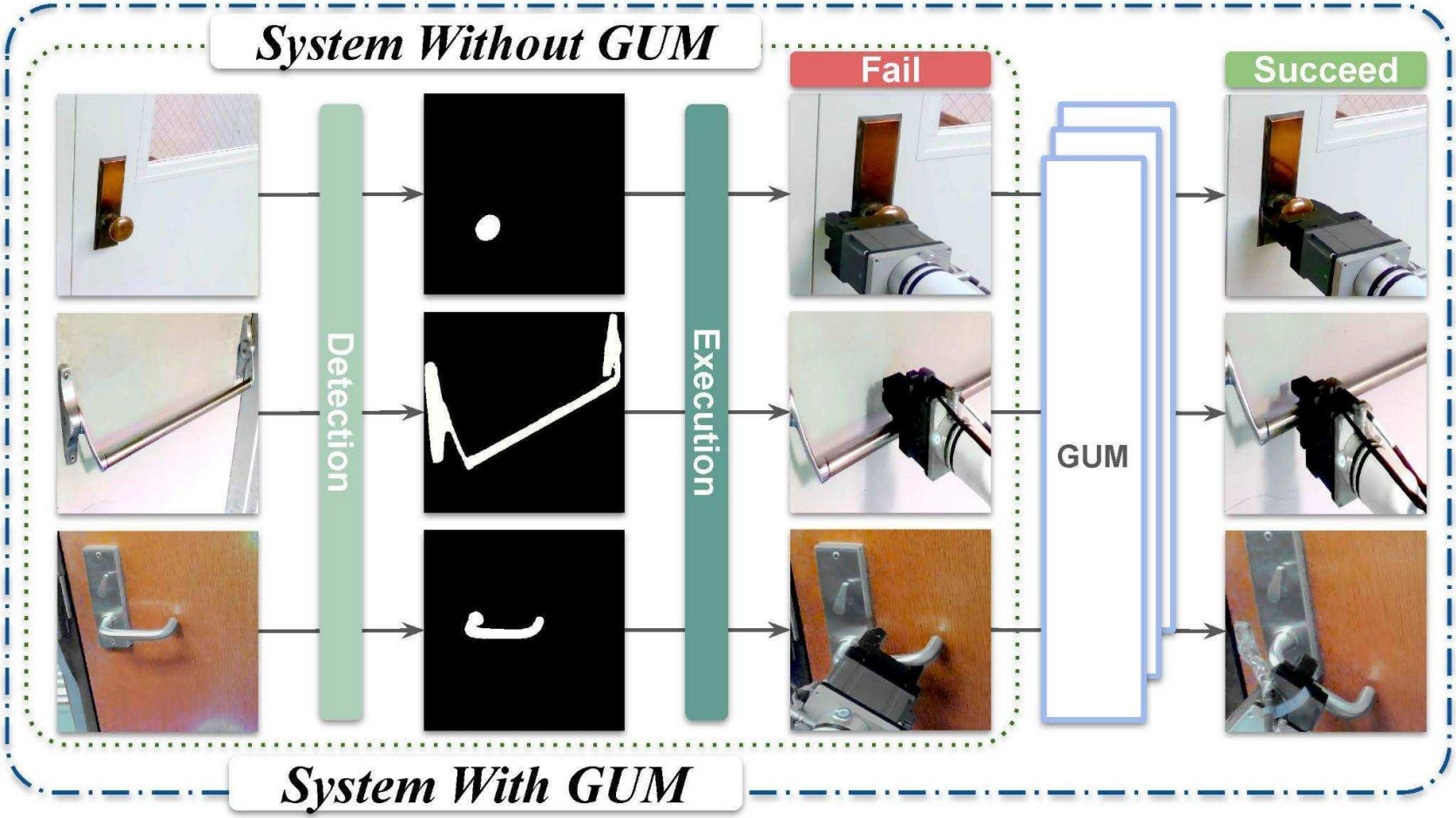
Appendix - DoorBot - System Architecture



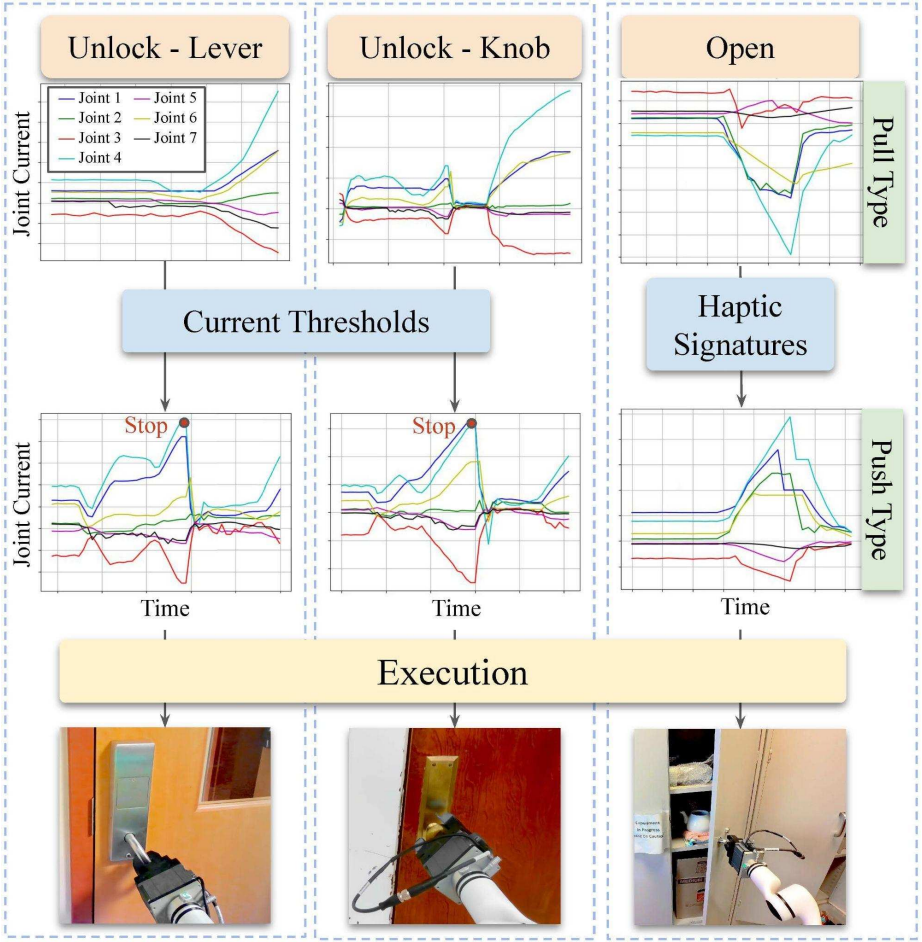
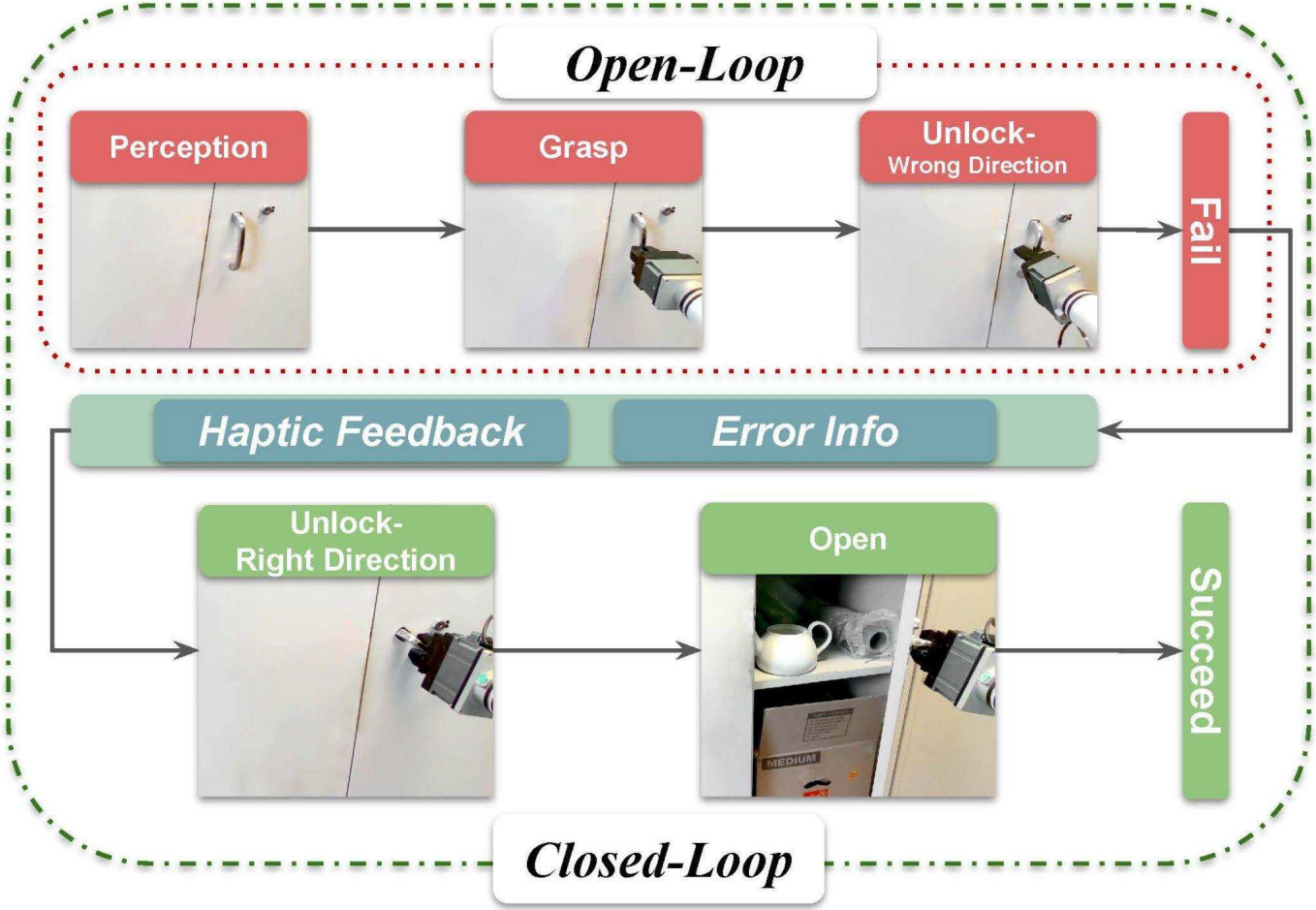
Appendix - DoorBot - State Machine



Appendix - DoorBot - GUM



Appendix - DoorBot - Haptic Feedback



Appendix - DoorBot - Closed-Loop System