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

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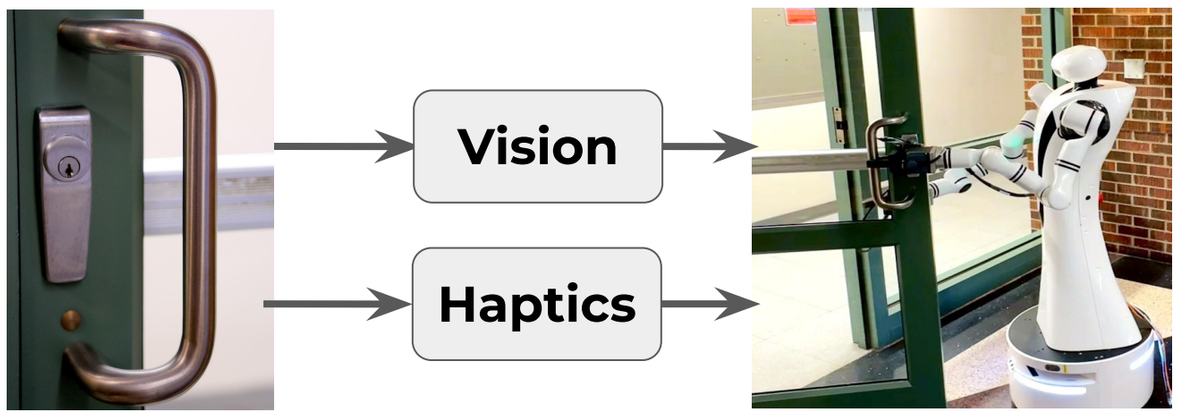
RoboTouch Lab @ ILLINOIS TSINGHUA

tx-leo.github.io/DoorBot

Objective: Open the Door!



Env: In the wild

Perception: Multimodality

Action: Opening Door

Challenges

[C1] With **limited demonstration / simulator support**, how can a robot **generalize** to open various door types (Lever / Knob / Crossbar / Cabinet) in the wild?

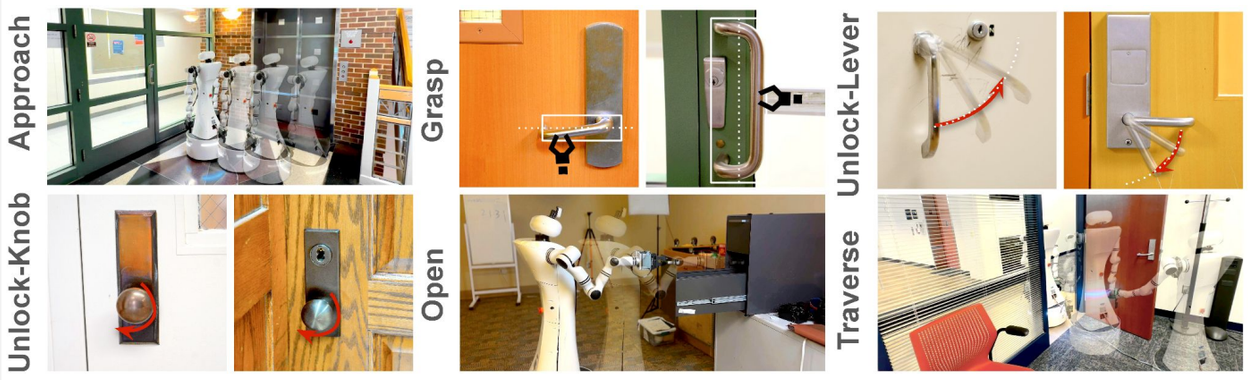
[C2] **Existing VLMs cannot** solve this task alone. How can our own **vision** modules efficiently help a robot grasp and unlock door handles?

[C3] **Vision is not enough** in contact-rich tasks. How can **haptics (touch)** guide the robot to decide pull/push, rotate left/right, know when to stop, ...

System: Hierarchical, data-efficient [C1]

High-Level planner: State machine

Low-Level controller: 6 motion primitives



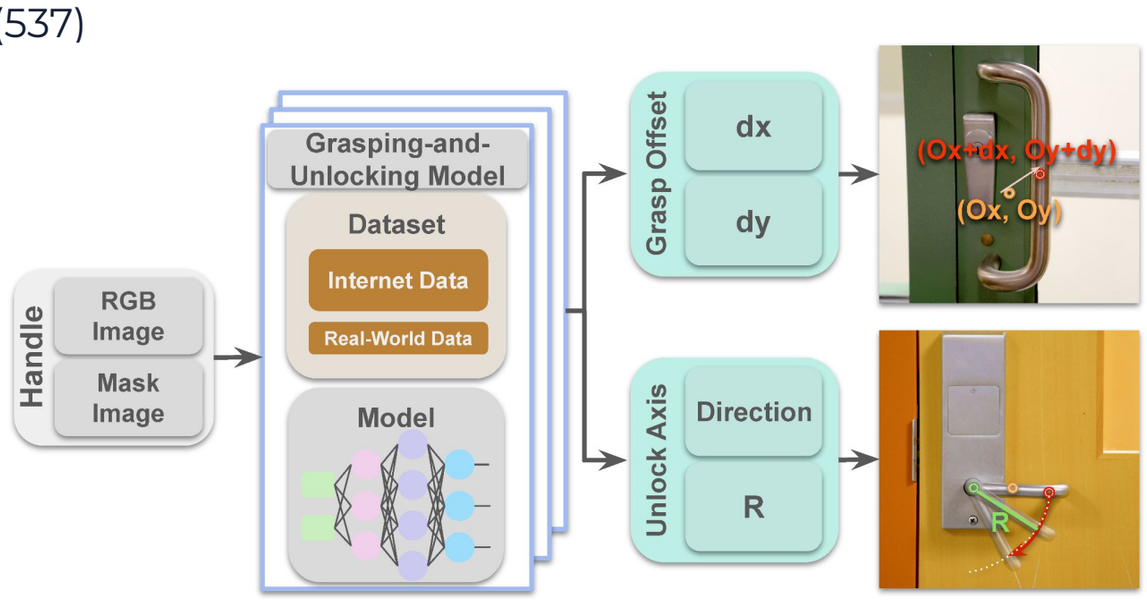
6 Primitives: Approach / Grasp / Unlock-Lever / Unlock-Knob / Open / Traverse

Generalization comes from

- Low-level primitives are guided by vision + haptic, with feedback control / DMP
- High-level planner utilizes multimodal feedback for transition

Vision: Grasping-and-Unlocking Model (GUM) [C2]

- **Grasp Offset:** Detect the **grasp point**
- **Unlock Axis:** Generate the **motion trajectory**
- **Dataset:** **1303** images from Internet (766) and real-world (537)

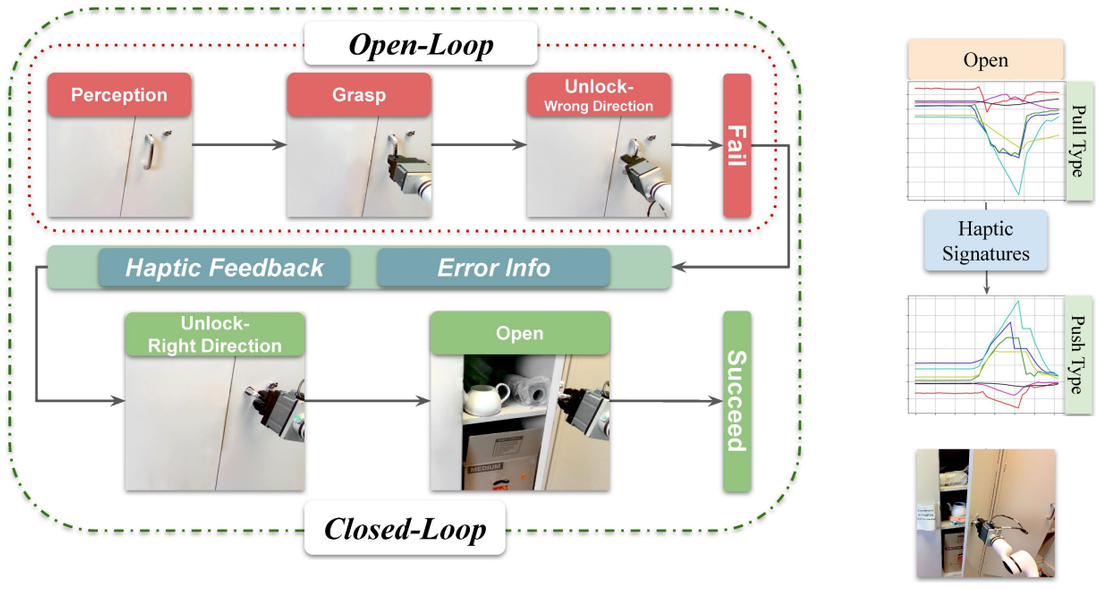


Fine-tuning Detic + SAM

with VLM: 5/25 (20%)
with GUM: **25/25 (100%)**

Haptics: Closed-Loop System with Haptic Feedback. [C3]

Haptic Feedback is essential
Unlocking: Tells the robot when to stop unlocking.
Opening: Tells the type of the door. (Push-/Pull-Door)
Elbow joint current reading serves as haptic signal



Haptic feedback enables runtime **explore-and-adapt**

Method	Is it grasping				push or pull
	grasp	unlock	rotate	open	
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%

VLM vs. Haptics

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

Open vs. Closed Loop

Experiments & Results

Backbone		Lever	Knob	Crossbar	Drawer	Sum
Planner	Controller					
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%***

(4 types * 5 = **20 unseen doors**) * (5 trials each door) = **100 trials** in total

Result: 90% success rate over 100 trials (Baseline: 40%)