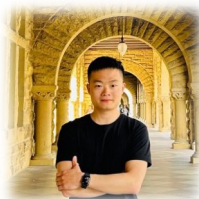


# Demystifying Diffusion Policies: Action Memorization and Simple Lookup Table Alternatives



Chengyang He



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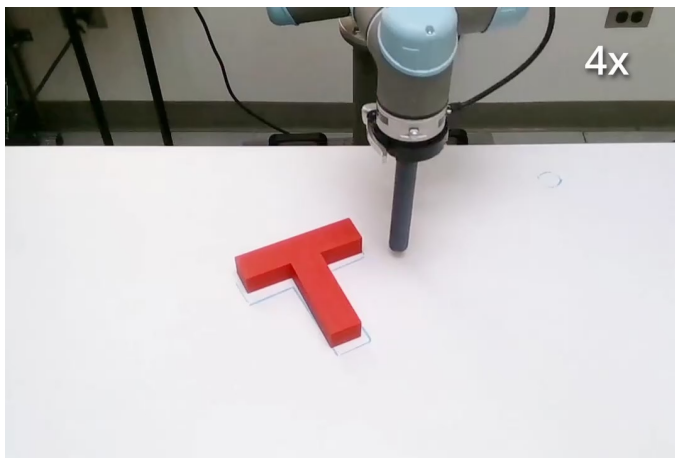
Mac Schwager



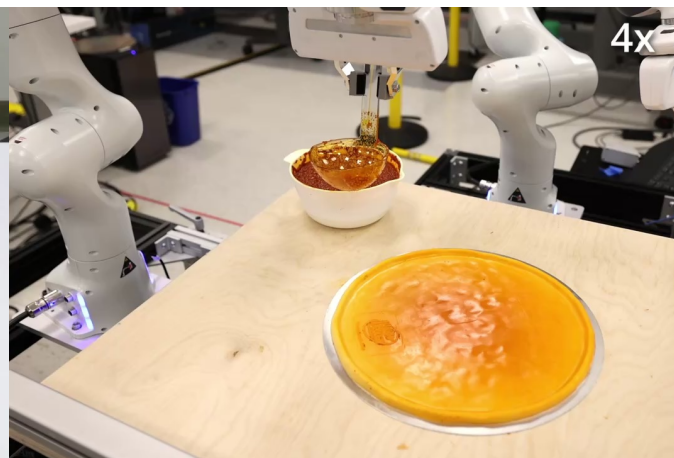
# Hypothesis

*Why do diffusion policies trained to overfit small data sets appear to give strong test-time performance in robot manipulation?*

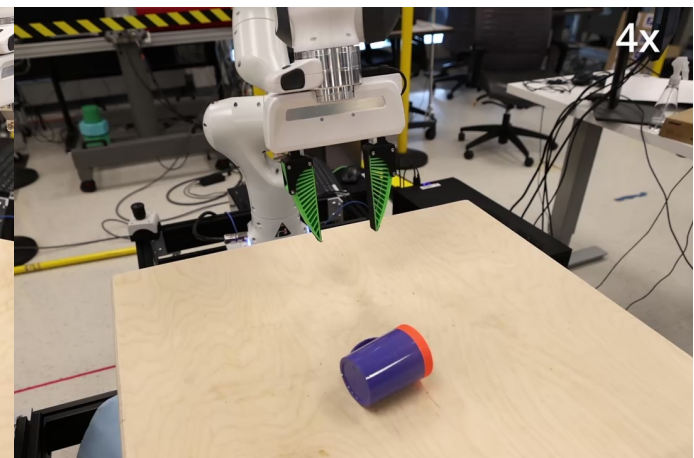
Push T\*



Sauce Pouring\*



Cup Placement\*



# Hypothesis

*Why do diffusion policies trained to overfit small data sets appear to give strong test-time performance in robot manipulation?*

**Diffusion policies essentially memorize an action lookup table — *and this is beneficial.***

*Can the same action memorization behavior be accomplished with a simpler, faster model architecture to yield faster runtime performance?*

# Diffusion Model Analysis

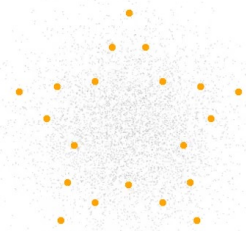
Low-capacity  
model, small data

Low-capacity  
model, large data

High-capacity  
model, small data

High-capacity  
model, large data

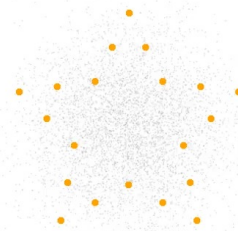
STAR Diffusion Step 1/100



STAR Diffusion Step 1/100



STAR Diffusion Step 1/100

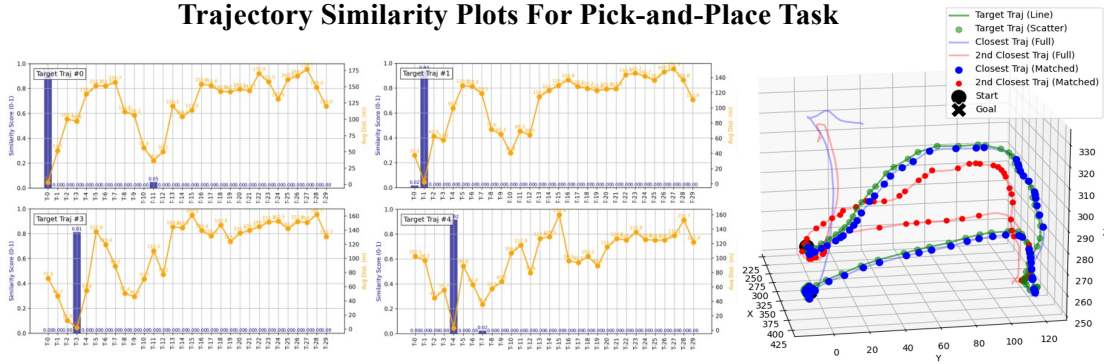


STAR Diffusion Step 1/100



# Diffusion Model Analysis

### Trajectory Similarity Plots For Pick-and-Place Task



### Trajectory Similarity Plots For Simulated Tasks

	Epochs	# Demos	Image Obs.	Epochs	# Demos	Low Dimensional
Can	1150	200	0.828 (4.032)	750	200	0.765 (5.408)
Square	2600	200	0.885 (2.086)	1750	200	0.799 (3.538)
Lift	300	200	0.578 (4.196)	450	200	0.580 (4.092)
Tool Hang	2650	200	0.962 (0.563)	3750	200	0.932 (1.016)
Transport	2750	200	0.965 (0.860)	2800	200	0.904 (2.356)
Block Push	-	-	-	4800	1000	0.963 (0.322)
Kitchen	-	-	-	4600	566	0.704 (14.231)

- Strong similarity to training trajectories in InD
- Holds for both Simulated and real-world tasks
- Training Similarity:

$$\mathcal{S} = 1 - \frac{s(\tau^{(r)}, \tau^{(1)})}{s(\tau^{(1)}, \tau^{(2)})}$$

- Average Euclidean Distance to closest training trajectory:  $s(\tau^{(r)}, \tau^{(1)})$
- Average Euclidean Distance to second closest training trajectory:  $s(\tau^{(1)}, \tau^{(2)})$

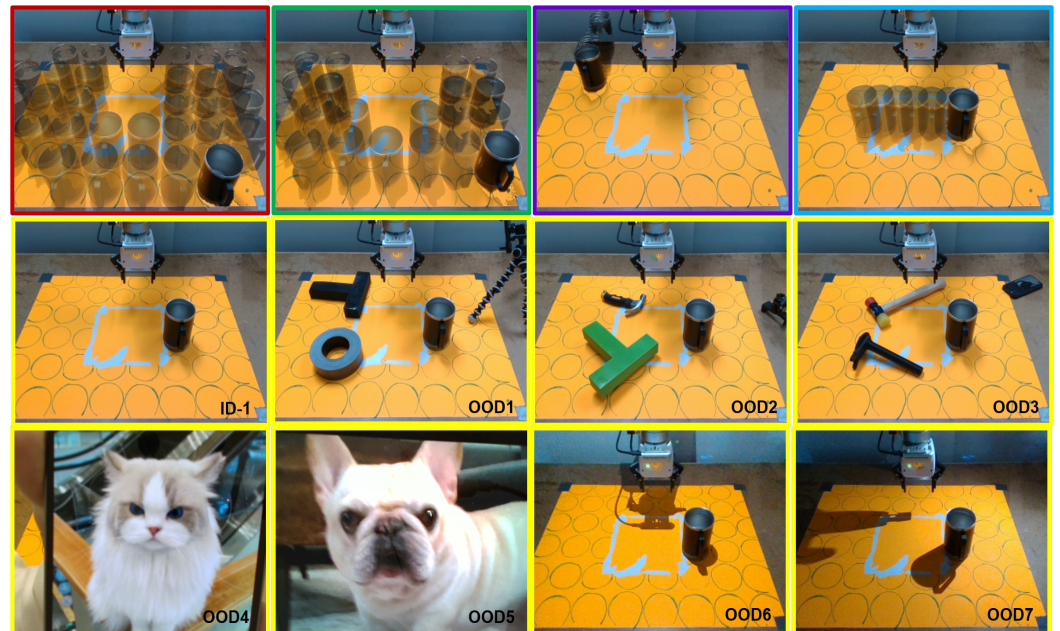
# Diffusion Model Analysis

## In-Distribution:

- Cup placed at training locations (Red)
- Locations interpolated between training locations (green)

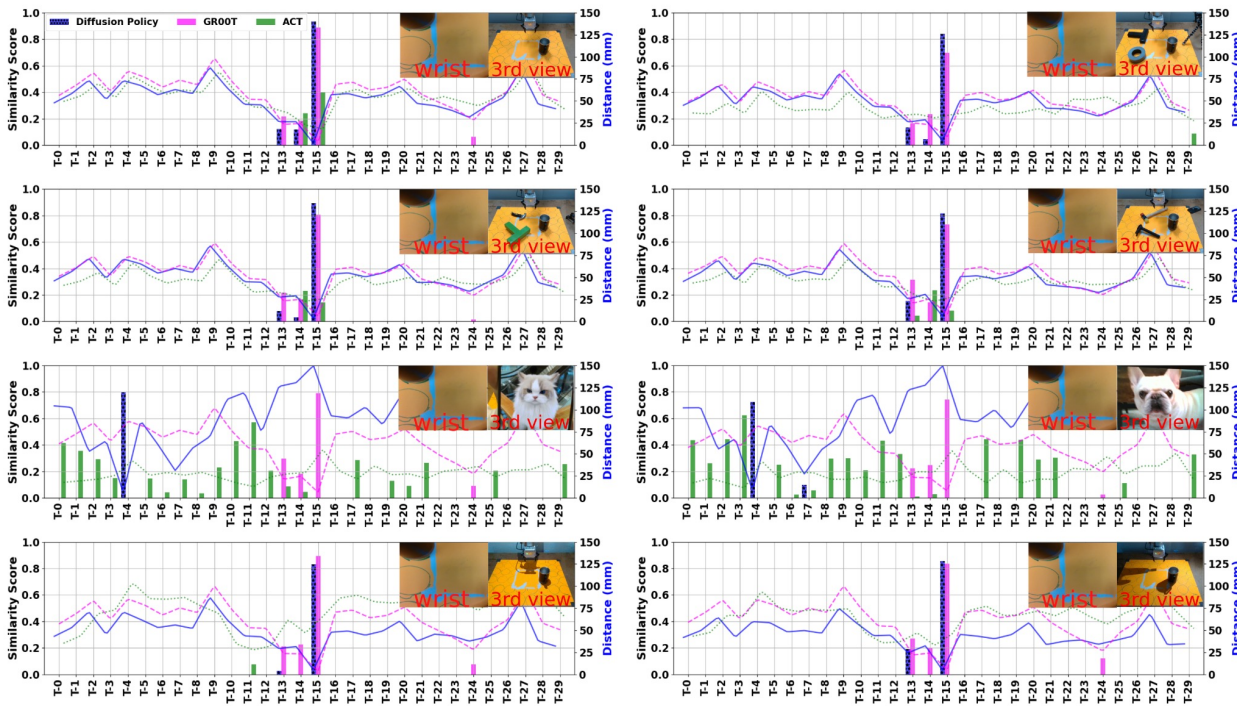
## Out-of-Distribution:

- Outside training distribution (Purple/Blue)
- Distractors added (Yellow)
- Corrupted observations (Yellow)
- Variations in lighting (Yellow)



# Diffusion Model Analysis

Trajectory Similarity Plots For Pick-and-Place Task Under OOD Conditions



## Diffusion Policy:

- Strong similarity to training trajectories even under OOD

## ACT:

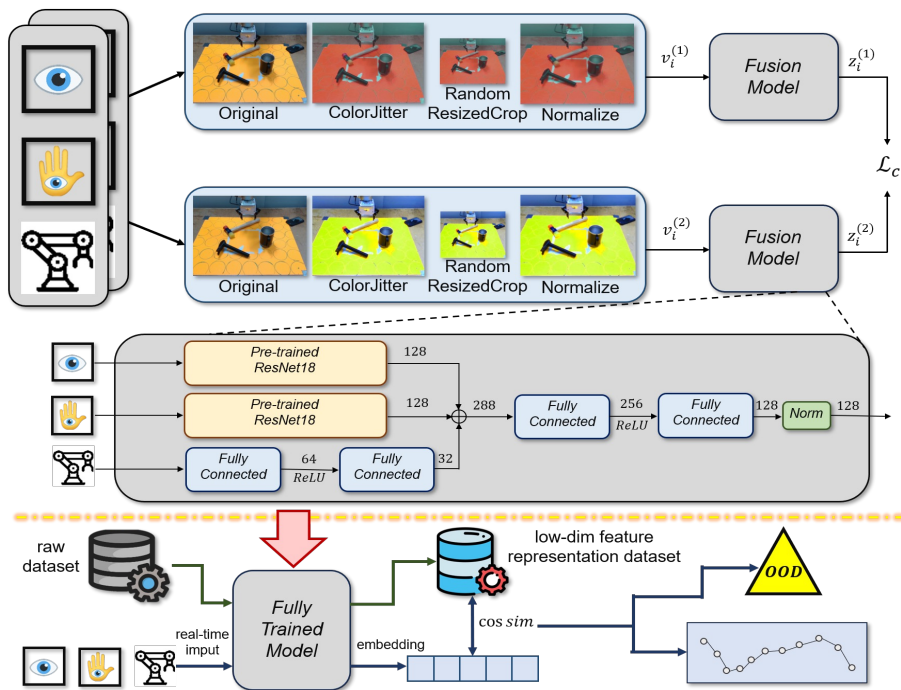
- Displays action generalization in both InD and OOD events
- Brittle when exposed to OOD situations

## GR00T:

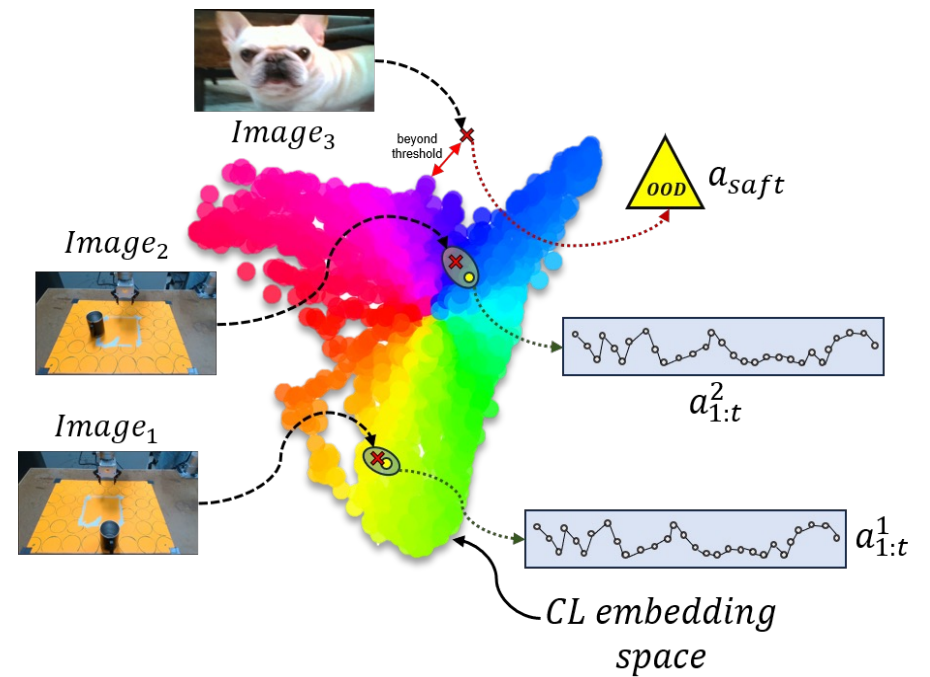
- Displays mix of interpolation and Memorization during OOD situations

# Action Lookup Table (ALT) Policy

## ALT Policy



## ALT Mechanism



# Action Lookup Table (ALT) Policy Analysis

## Advantages:

Less Inference Time:  $\sim 0.009s$  vs  $\sim 2.65s$

Smaller Model Scale: **45.5MB** vs 5.3 GB

Clear OOD detection mechanism.

Encoder Backbone Ablation

Encoder-Dim	InDs	InD-1	OOD1	OOD2	OOD3	OOD4	OOD5	OOD6	OOD7
ResNet-64	100%	✓	✓	✓	✓	✗	✗	✓	✓
ResNet-128	100%	✓	✓	✓	✓	✗	✗	✓	✓
ResNet-256	100%	✓	✓	✓	✓	✗	✗	✓	✓
SimpleCNN-64	19.35%	✗	✗	✗	✗	✗	✗	✗	✗
SimpleCNN-128	22.58%	✗	✗	✗	✗	✗	✗	✗	✗
SimpleCNN-256	22.58%	✗	✗	✗	✗	✗	✗	✗	✗
ViT-64	12.9%	✓	✓	✓	✓	✓	✓	✓	✗
ViT-128	12.9%	✓	✓	✓	✓	✓	✓	✓	✓
ViT-256	16.13%	✗	✗	✗	✗	✗	✗	✗	✗
CLIP-64	22.58%	✓	✓	✓	✓	✗	✗	✗	✗
CLIP-128	100%	✓	✓	✓	✓	✗	✗	✗	✗
CLIP-256	51.61%	✓	✓	✗	✓	✓	✓	✗	✗
Swin-64	77.42%	✓	✓	✓	✓	✗	✗	✓	✓
Swin-128	83.87%	✓	✓	✓	✓	✓	✗	✓	✓
Swin-256	90.32%	✓	✓	✓	✓	✓	✗	✓	✓

ALT vs Diffusion Policy and K-D Tree

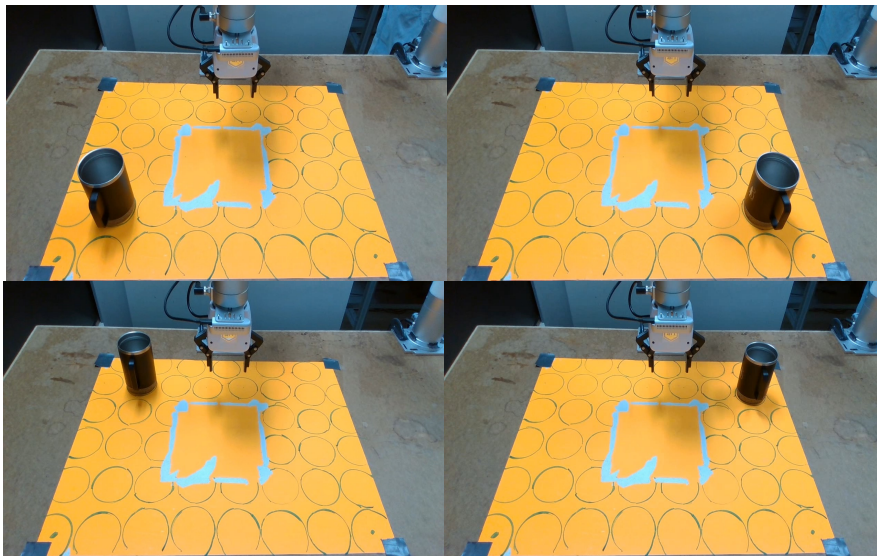
Methods	Recall	IDs	ID-1	OOD1	OOD2	OOD3	OOD4	OOD5	OOD6	OOD7	MIT
K-D Tree	100%	63.3%	✓	✓	✓	✓	✓	✗	✓	✓	$\sim 0.09$
Diffusion Policy	100%	100%	✓	✓	✓	✓	✗	✗	✓	✓	$\sim 2.65$
Ours w/ p, $\gamma = 0.9$	100%	-	✓	✓	OOD	OOD	OOD	OOD	OOD	✓	$\sim 0.009$
Ours w/o p, $\gamma = 0.9$	100%	-	✓	OOD	OOD	OOD	OOD	OOD	OOD	OOD	$\sim 0.009$
Ours w/o p, $\gamma = 0.75$	100%	100%	✓	✓	✓	✓	✓	✓	OOD	OOD	$\sim 0.009$

## Key:

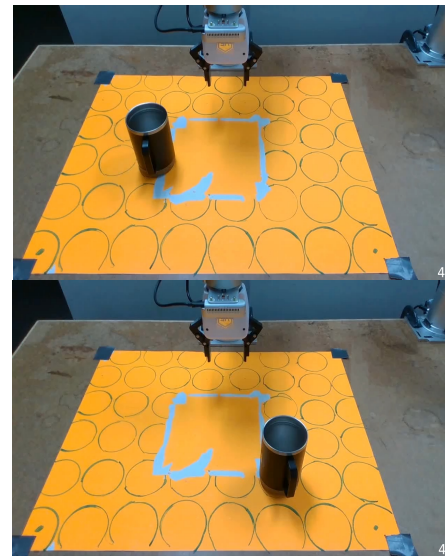
Icon	Rollout	Detection
✓	Correct	--
✗	Incorrect	--
OOD	Incorrect	Correct
OOD	Correct	Correct

# Action Lookup Table (ALT) Policy Analysis

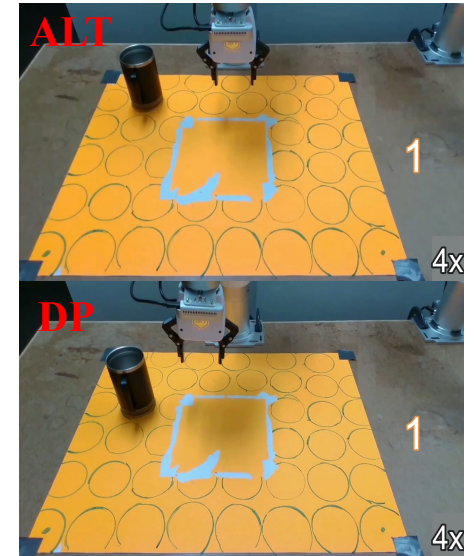
## Robust InD Trajectory Recall

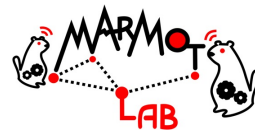


## Multimodal



## Reactive





ICLR 2026, Rio De Janeiro.