Universität Hamburg
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MIN Faculty
Department of Informatics

Learning Perception and Manipulation of Clothes

Research Survey

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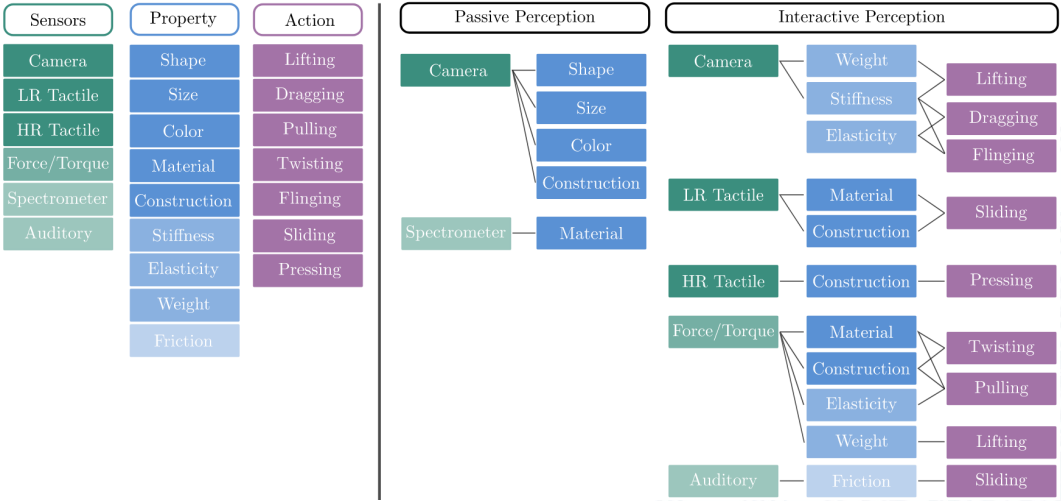
Technical Aspects of Multimodal Systems

January 28, 2025

Outline

1. Clothes/Fabric Specific Work
2. Diffusion Policy Advancements
3. My Future Plans

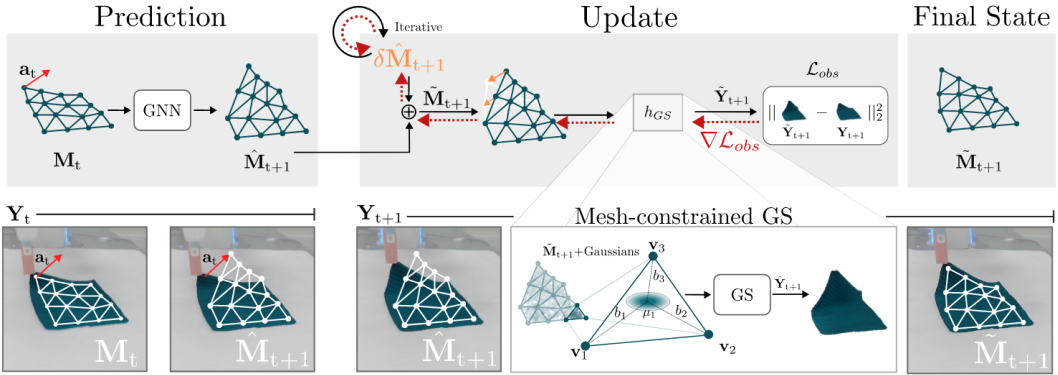
Clothes Perception



Unfolding the Literature: A Review of Robotic Cloth Manipulation, Longhini et al.,

Annual Review of Control, Robotics, and Autonomous Systems 2025

Cloth Splatting



Cloth-Splatting: 3D Cloth State Estimation from RGB Supervision, Longhini et al., CoRL 2024

Tasks

Frequency	Household	Healthcare	Textile Industry
Frequent (4+)	Folding, Smoothing, Ironing	Dressing	
Rare (2-3)	Hanging, Sorting, Wiping	Bedding, Bed-making, Bandaging	Recycling
Unaddressed (0-1)	Storing	Buttoning	Manufacturing, Dyeing, Quality control, Coloring, Washing

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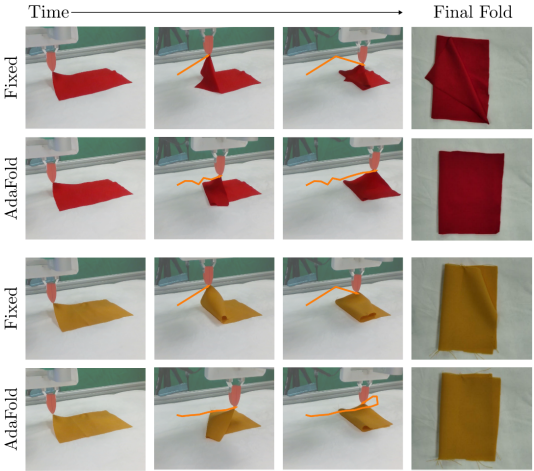
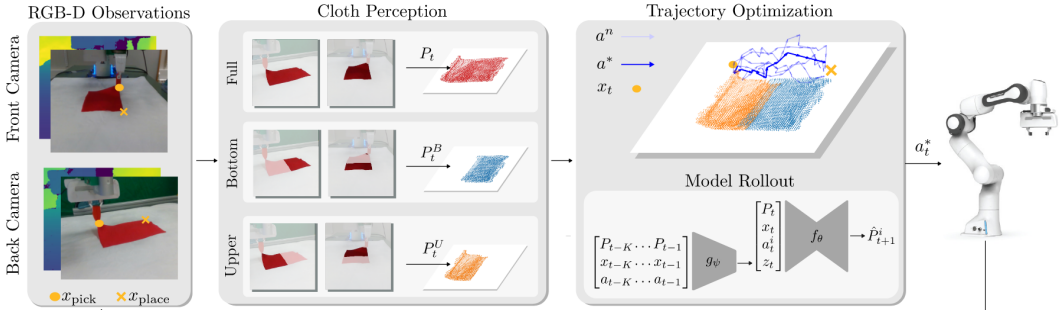
Ada Fold



AdaFold: Adapting Folding Trajectories of Cloths via Feedback-loop Manipulation, Longhini et al.,

Robotics and Automation Letters 2024

Ada Fold



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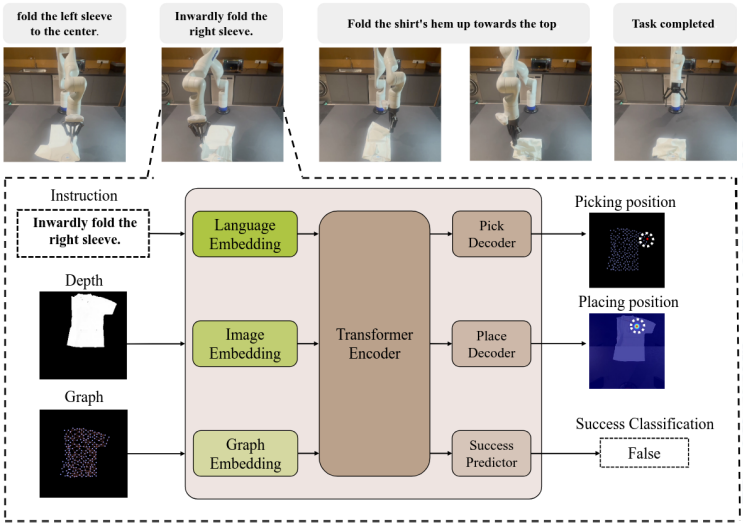
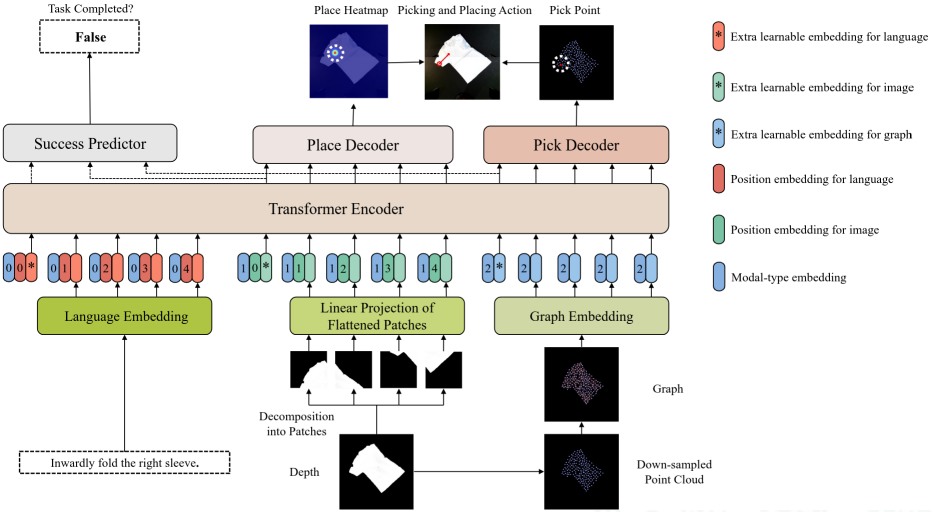
Language-Conditioned Deformable Object Manipulation



Learning Language-Conditioned Deformable Object Manipulation with Graph Dynamics, Deng et al., ICRA 2024

Language-Conditioned Deformable Object Manipulation



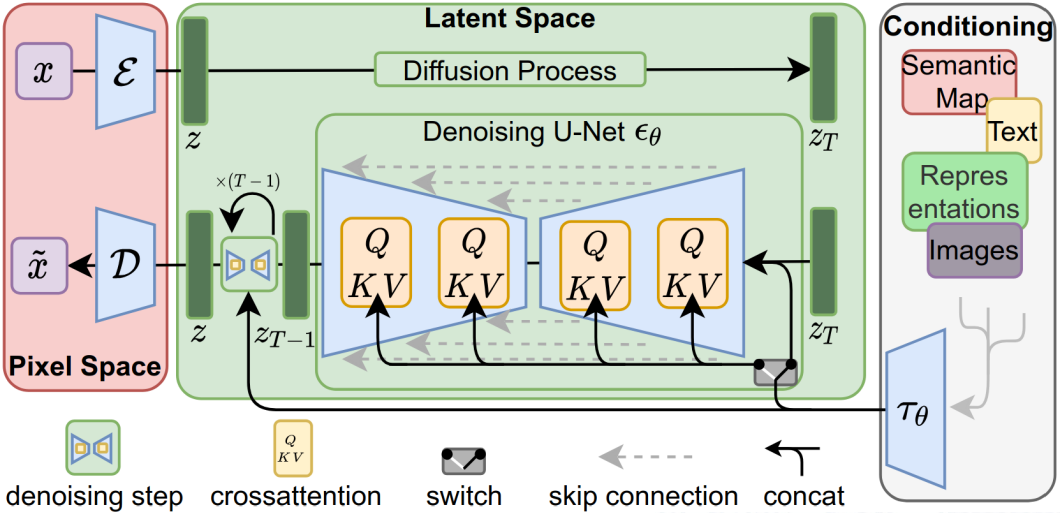
Learning Language-Conditioned Deformable Object Manipulation with Graph Dynamics, Deng et al., ICRA 2024

Diffusion Fundamentals

- Originally Text-to-Image generative models
- Alternative to Generative Adversarial Networks (GANs)
  - Several useful advancements
  - Higher image resolution
  - More stability during training

https://insights.daffodilsw.com/blog/all-you-need-to-know-about-diffusion-models

Diffusion Fundamentals



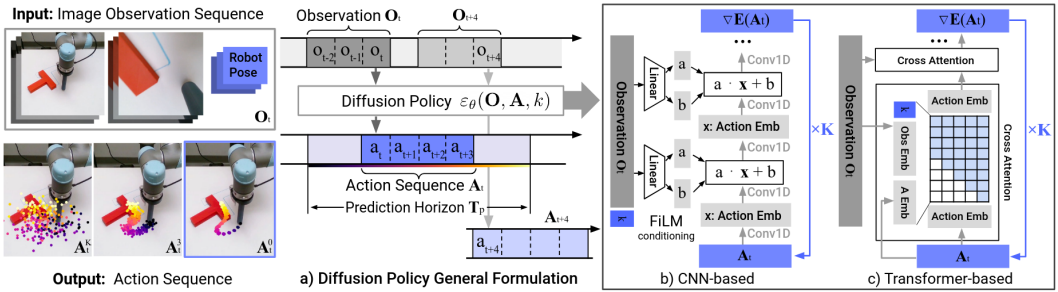
High-

Resolution Image Synthesis with Latent Diffusion Models, Rombach et al., CVPR 2022

Diffusion Policy

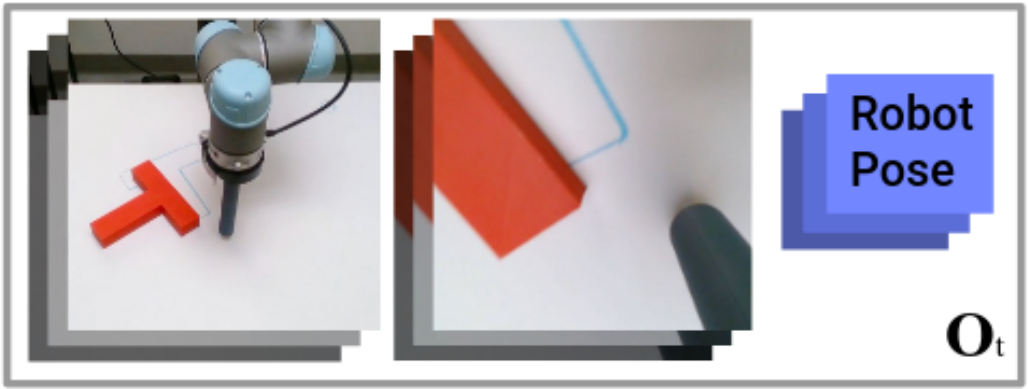
- Basic idea: Generate robot actions instead of images
- Use system state encoding as denoising conditions
- Use demonstrations as training data

Diffusion Policy



Diffusion Policy: Visuomotor Policy Learning via Action Diffusion, Chi et al., The International Journal of Robotics Research 2024

Diffusion Policy Input



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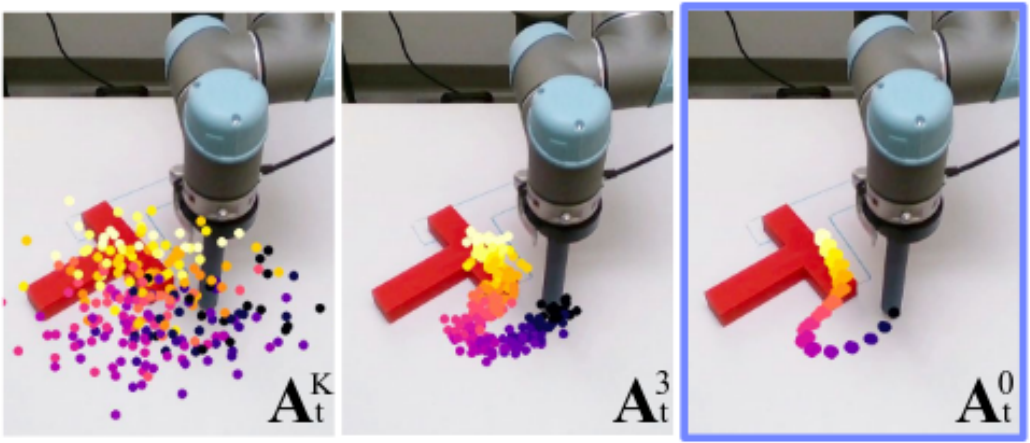
Diffusion Policy Output



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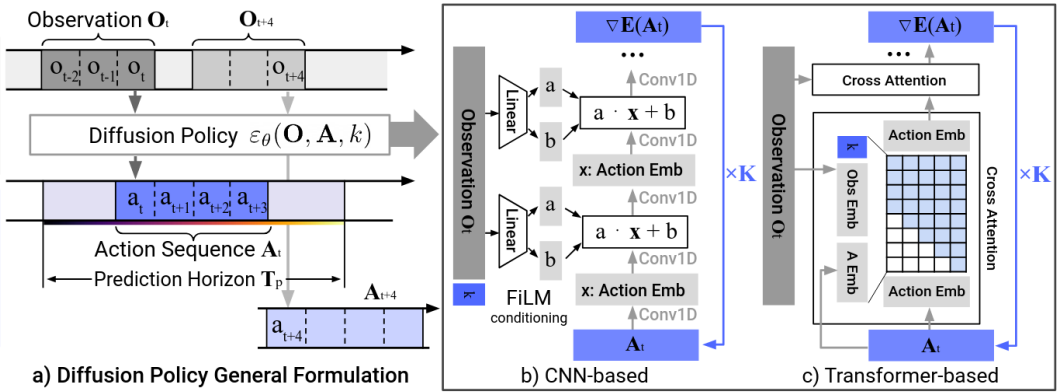
Diffusion Policy Architecture



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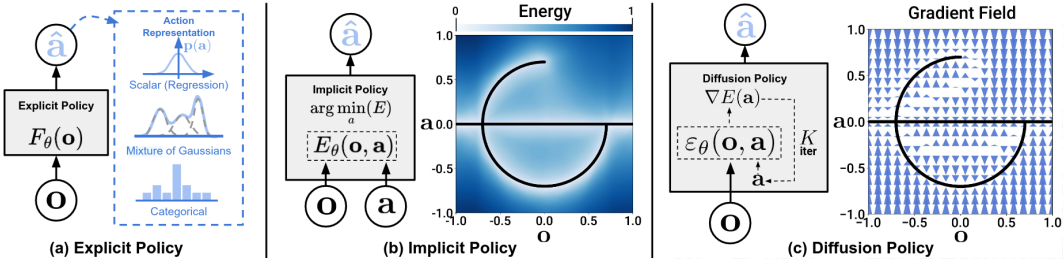
Policy Representations



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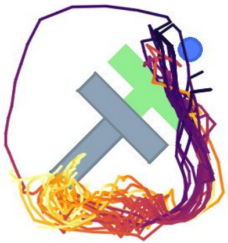
Multimodal Behavior

Diffusion Policy



LSTM-GMM

BET

IBC

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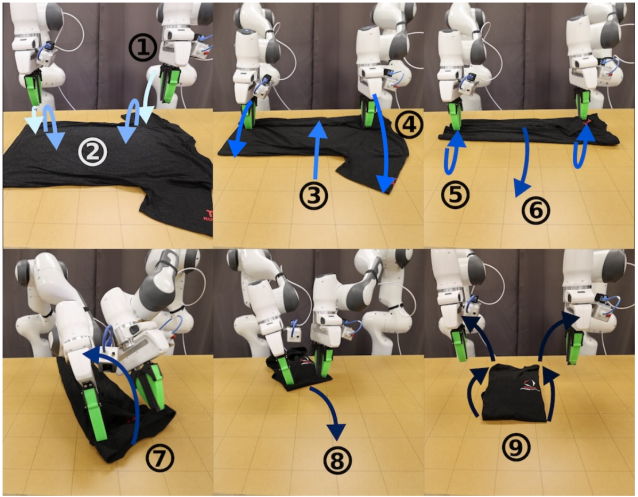
Diffusion Policy for Clothes



- Folding one specific T-shirt (same as in demonstration)
- 284 demonstrations for training
- Success rate of 75% over 20 trials
- Demonstration and policy rollout using VR controllers and collision avoidance (similar to TAMS setup)

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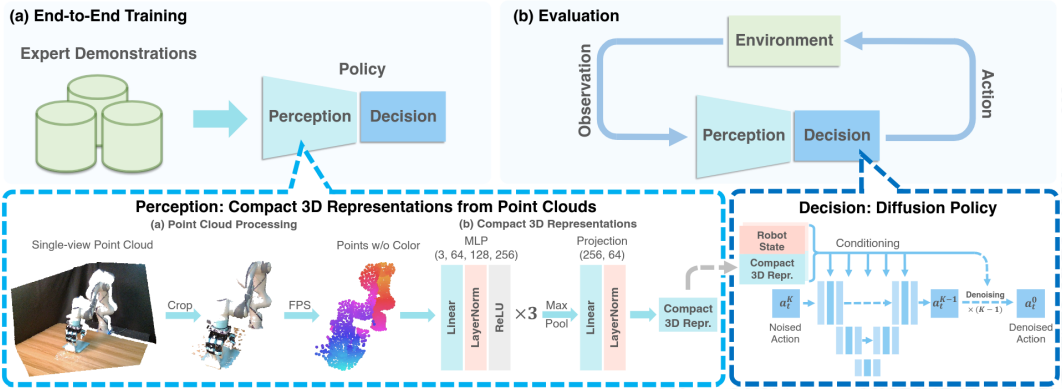
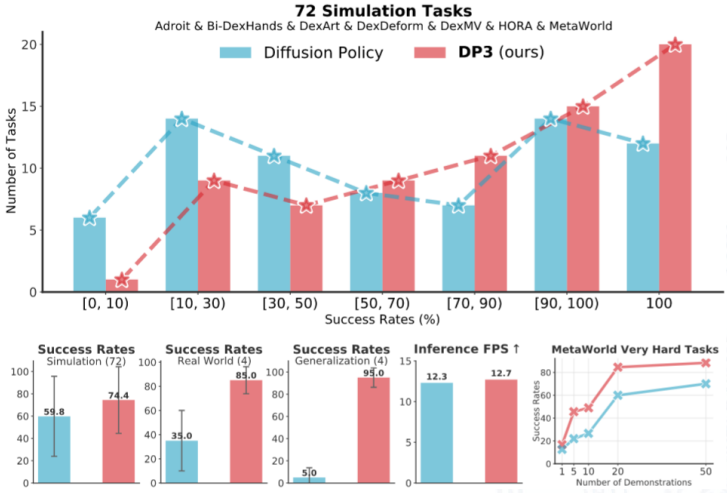
3D Diffusion Policy



3D Diffusion Policy: Generalizable Visuomotor Policy Learning via Simple 3D Representations, Ze et al., Robotics: Science and Systems 2024

3D Diffusion Policy



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3D Diffusion Policy

Encoders	Conv	w/ T-Net	w/ BN	1024 Dim	**Average**
PointNet	✓	✓	✓	✓	15.7
	✗	✓	✓	✓	15.7
	✓	✗	✓	✓	16.0
	✗	✗	✓	✓	26.0
	✗	✓	✓	✗	18.2
Turnaroud!	✓	✗	✗	✓	**72.5**
	✗	✗	✓	✗	19.8
	✗	✓	✗	✗	26.8
	✗	✗	✗	✗	**72.3**

3D Diffusion Policy: Generalizable Visuomotor Policy Learning via Simple 3D Representations, Ze et al., Robotics: Science and Systems 2024

3D Diffusion Policy

Designs	H	D	P	A	DA	SP	**Average**
DP3	**100±0**	62±4	43±6	**99±1**	69±4	97±4	**78.3**
w/o cropping	98±1	**69±3**	14±1	19±9	32±6	40±2	45.3
w/o LayerNorm	**100±0**	56±4	44±3	96±2	51±3	91±5	73.0
w/o sample pred	68±3	67±8	37±12	96±2	58±9	76±9	67.0
w/o projection	**100±0**	61±2	**47±3**	**99±1**	60±8	**99±2**	77.7
w/ color	**100±1**	67±3	46±4	76±8	**75±5**	68±3	72.0
DDIM→DPM-solver++	12±4	9±5	26±5	93±3	58±6	92±14	48.3

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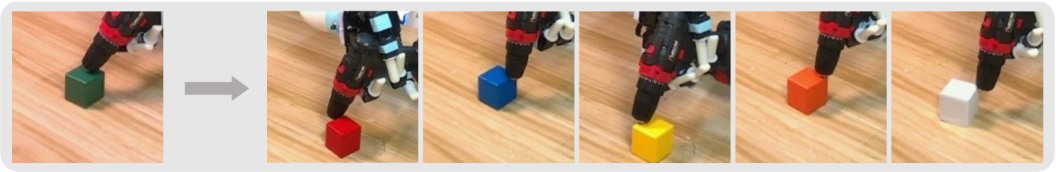
3D Diffusion Policy Generalization



Apperance Generalization (■)	■	■	■	■	■
Diffusion Policy	✗	✗	✗	✗	✗
Diffusion Policy (Depth)	✗	✗	✗	✗	✗
DP3	✓	✓	✓	✓	✓

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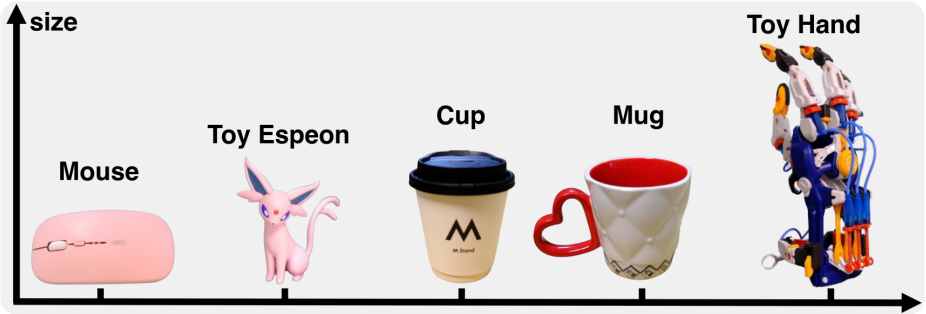
3D Diffusion Policy Generalization



Instance Generalization	Mouse	Espeon	Cup	Mug	Hand
Diffusion Policy	✗	✗	✗	✗	✓
Diffusion Policy (Depth)	✗	✗	✓	✗	✗
DP3	✓	✓	✓	✓	✓

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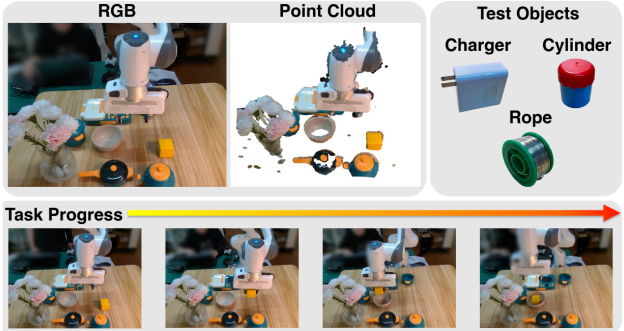
3D Diffusion Policy Generalization



Cluttered Scenes	Diffusion Policy	DP3 w/ PointNeXt	DP3 w/ color	DP3
Success Rate	60	0	**80**	**80**

Train with ■ Cube	■	■	■	Charger	Cylinder	Rope
DP3 w/ color	✗	✗	✗	✗	✗	✗
DP3	✓	✓	✓	✓	✓	✓

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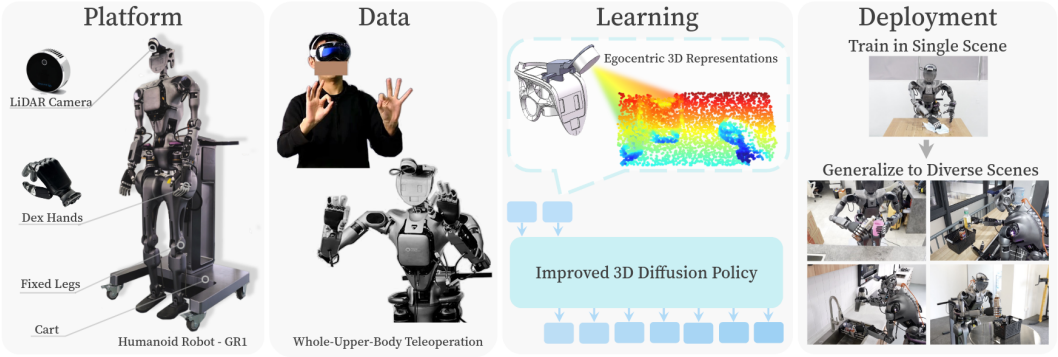
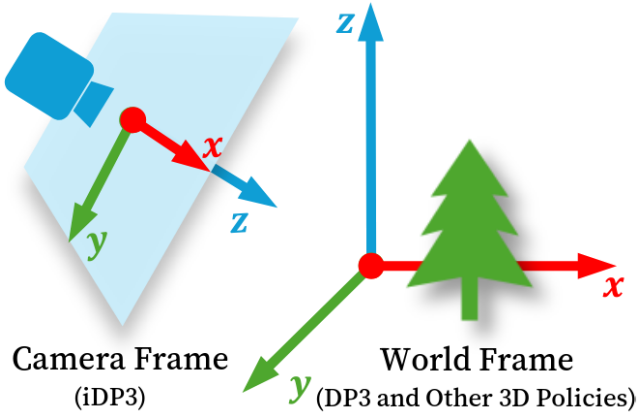
Mobile Robot 3D Diffusion Policy



Generalizable Humanoid Manipulation with Improved 3D Diffusion Policies, Ze et al., arXiv 2024

Mobile Robot 3D Diffusion Policy



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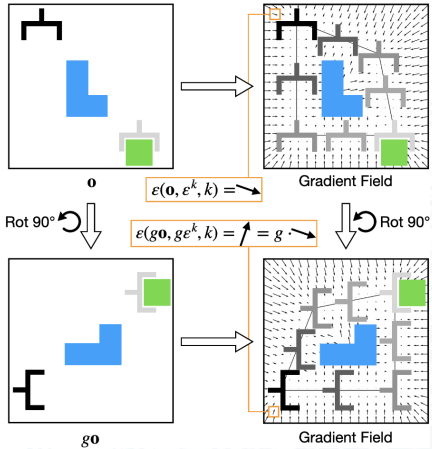
Equivariant Diffusion Policy

- Utilize domain symmetries
- Increases sample efficiency and generalization



Equivariant Diffusion Policy, Wang et al., CoRL 2024

Equivariant Diffusion Policy

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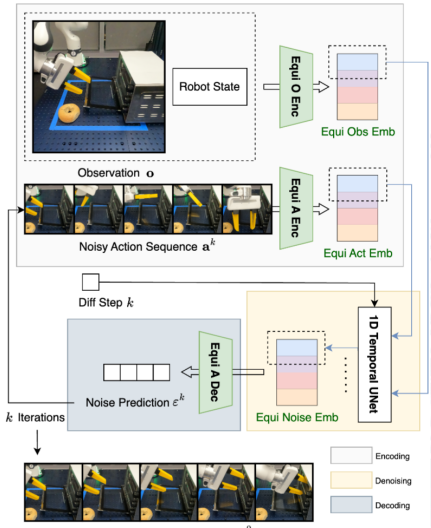

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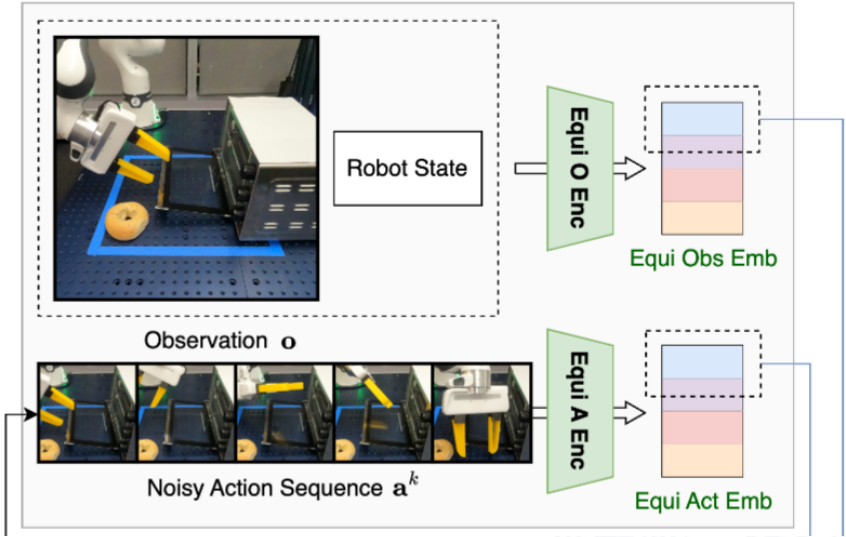

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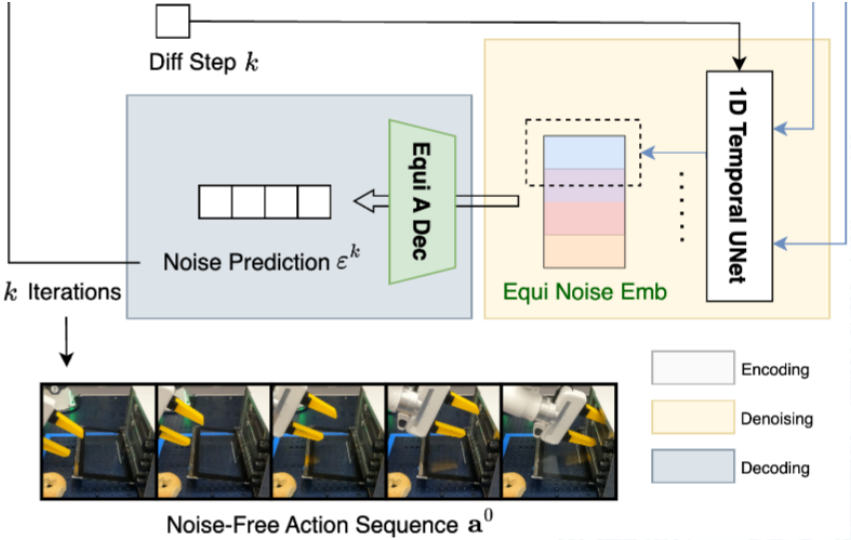
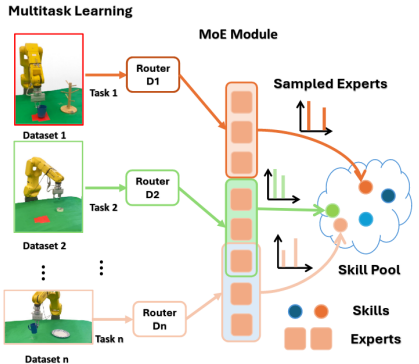
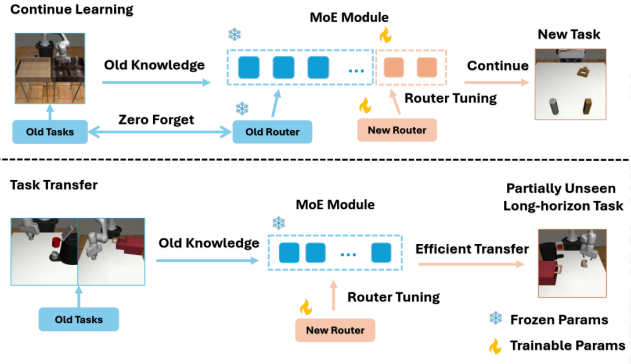


Equivariant Diffusion Policy, Wang et al., CoRL 2024

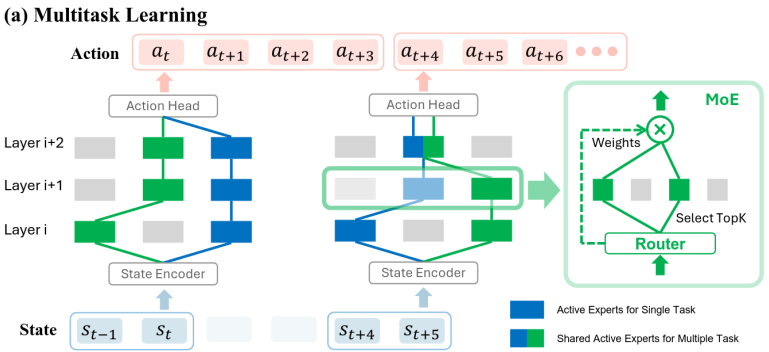
Sparse Diffusion Policy





Sparse Diffusion Policy: A Sparse, Reusable, and Flexible Policy for Robot Learning, Wang et al., CoRL 2024

Sparse Diffusion Policy



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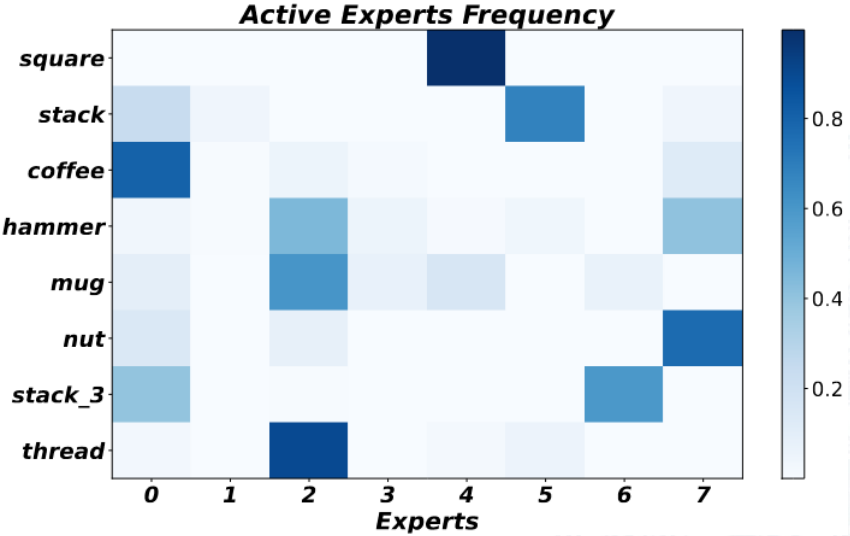

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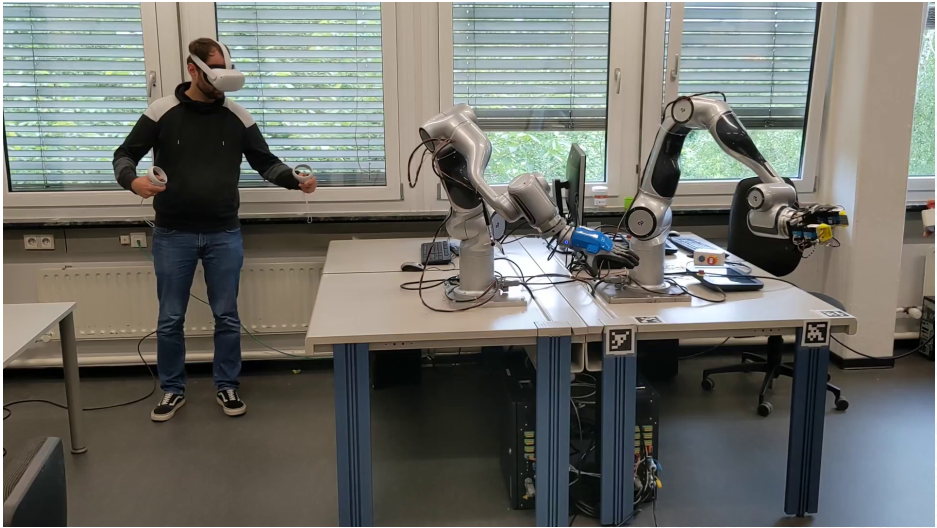
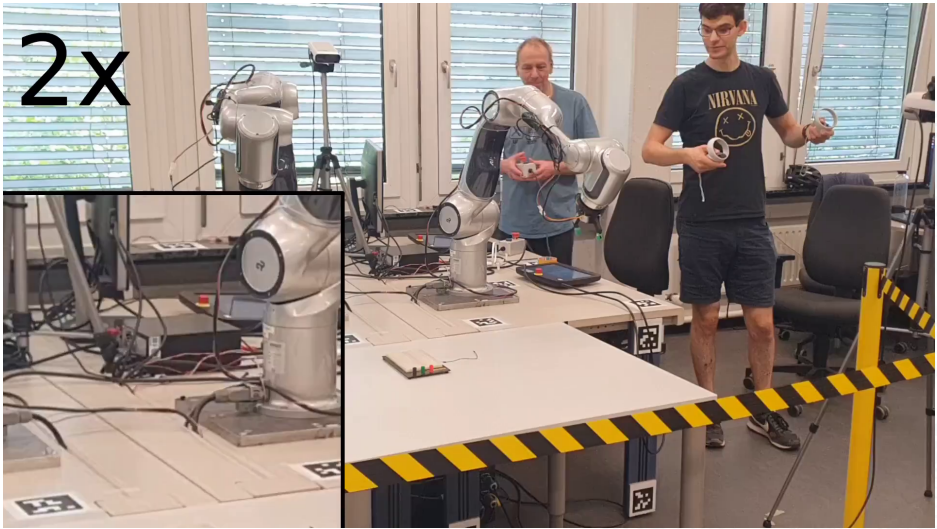
Demonstrations in VR



Demonstrations using VR Controllers



Future Tasks

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Future Plans

- **Get some diffusion policy running on the dual Diana7 setup** and build clothes demo
  - Initially with image input
  - Try tasks with point cloud input
  - Figure out how to use point clouds with clothes/fabrics
- Explore rarely addressed and unaddressed tasks
  - Quality control using event cameras?