Supplementary Materials for "FlowPolicy: Enabling Fast and Robust 3D Flow-based Policy via Consistency Flow Matching for Robot Manipulation"

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More Implementation Details

For the reproducibility of the experiments, we list more details of the experiments as shown in Table S1, including the hyperparameter settings for each component and consistency flow matching. Most of the settings are consistent with DP3 (Ze et al. 2024). In addition, we run three random seeds for each task. The reported success rates are the mean and variance under three random seeds.

More Experimental Results

We present the average success results for all tasks in Table S2, and Table S3 shows the average running time for all tasks as a complement to the experimental results in the main paper. Observing Table S2 shows that FlowPolicy achieves state-of-the-art results on the most of tasks. Although FlowPolicy's success rate on individual hard tasks is slightly lower than that of DP3, we have shown that this situation can be resolved by increasing the number of demonstrations appropriately. As can be seen from Table S3, FlowPolicy has the shortest inference time. Compared to Simple DP3, FlowPolicy has less variance in executing a single task, suggesting that a stable execution policy can be attained for FlowPolicy even with one-step inference. In addition, we compare the one-step inference results of FlowPolicy with DP3, as shown in Table S4. The results similarly prove the effectiveness of FlowPolicy.

Video results

We have also included all of FlowPolicy's video results on Adroit and Metaworld as a supplemental illustration. Please refer to the 'index.html' file in the supplementary materials.

Limitation and Discussion

Although we have demonstrated the effectiveness of combining 3D conditional representations with consistency flow matching in robotic manipulation tasks, achieving real-time inference speed, our experiments were conducted in simulated environments. Therefore, the effectiveness of FlowPolicy in real-world scenarios remains to be validated, which is

Hyperparameter	Value
batch_size	128
num_epochs	3000
learning rate	1.0e-4
optimizer	AdamW
lr_scheduler	cosine
lr_warmup_Steps	500
EMA_decay	0.95
image_size	84∗84
point_cloud (Adroit)	512
point_cloud (Metaworld)	1024
encoder_output_dim	64
horizon	4
num_obs_steps	2
num_action_steps	4
Training	
num_segments	2
boundary	1
delta	1e-2
alpha	1e-5
eps	1e-2
Sampling	
eps	1e-2
noise_sacle	1
sigma_var	0.0
num_inference_step	1

Table S1: Detailed hyperparameters in our experiments.

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the primary limitation of our work. On the other hand, DP3 has already shown that 3D diffusion policies, when tested on virtual platforms like Adroit and Metaworld, can generalize well to the real world. We hope that the more robust Flow-Policy approach will be equally effective. We leave this issue as our future work.

Additionally, we have observed some issues with evaluation strategies on virtual platforms like Metaworld, where certain tasks are considered successful even when there are penetrations, which does not accurately reflect real-world robotic manipulation. Therefore, we also consider improving the design of demonstrations and evaluation criteria for robotic manipulation tasks as another future work.

References

Ze, Y.; Zhang, G.; Zhang, K.; Hu, C.; Wang, M.; and Xu, H. 2024. 3D Diffusion Policy: Generalizable Visuomotor Policy Learning via Simple 3D Representations. In *Proc. RSS*.

Methods \ Tasks	Adroit			Metaworld (Easy)				
	Hammer	Door	Pen	Button Press	Button Press Wall	Dial Turn	Door Close	Door Open
DP3	100±0	56±5	46±10	100±0	100±0	45±14	100±0	100±0
Simple DP3	98±2	40±17	36±4	100±0	100±0	58±9	100±0	100±0
FlowPolicy (Ours)	100±0	58±5	53±12	100±0	100±0	63±4	100±0	100±0

Methods \ Tasks	Metaworld (Easy)							
	Door Unlock	Drawer Close	Faucet Close	Faucet Open	Handle Press	Handle Pull	Lever Pull	Plate Slide
DP3	100±0	100±0	100±0	100±0	100±0	33±10	66±2	98±2
Simple DP3	98±2	100±0	100±0	100±0	98±2	28±10	61±2	98±2
FlowPolicy (Ours)	100±0	100±0	100±0	100±0	100±0	40±7	63±17	91±7

Methods \ Tasks	Metaworld (Easy)						
	Plate Slide Back	Plate Slide Back Side	Plate Slide Side	Reach	Reach Wall	Window Close	Window Open
DP3	100±0	100±0	100±0	51±8	65±8	100±0	100±0
Simple DP3	100±0	100±0	100±0	48±6	66±6	100±0	100±0
FlowPolicy (Ours)	100±0	100±0	100±0	80±9	83±8	100±0	100±0

Methods \ Tasks	Metaworld (Easy)	Metaworld (Medium)				Metaworld (Hard)	
	Peg Unplug Side	Coffee Pull	Hammer	Peg Insert Side	Soccer	Assembly	Hand Insert
DP3	76±4	50±14	90±4	25±8	13±9	75±10	25±7
Simple DP3	68±10	48±10	86±6	23±8	11±2	73±4	33±6
FlowPolicy (Ours)	76±7	55±14	95±3	20±8	20±6	85±6	23±7

Methods \ Tasks	Metaworld (Hard)		Metaworld (Very Hard)					**Average**
	Pick Place	Push	Shelf Place	Disassemble	Stick Pull	Stick Push	Pick Place Wall	
DP3	16±6	15±8	8±2	68±16	23±4	70±4	28±19	68.7±4.7
Simple DP3	11±8	38±12	8±2	63±16	18±4	58±13	28±23	67.4±5.0
FlowPolicy (Ours)	25±6	16±10	5±3	50±15	35±12	68±2	25±6	**70.0±4.7**

Table S2: Complete results for success rate. We report detailed success rate results for DP3 (Ze et al. 2024) and our FlowPolicy for each task in detail.

Methods \ Tasks	Adroit			Metaworld (Easy)				
	Hammer	Door	Pen	Button Press	Button Press Wall	Dial Turn	Door Close	Door Open
DP3	146.6±0.7	146.8±2.0	144.8±2.9	148.2±2.8	150.0±0.6	145.8±6.6	144.3±1.0	145.4±3.1
Simple DP3	64.5±1.4	64.2±2.4	71.2±9.3	61.6±1.5	63.4±2.2	76.0±10.1	65.3±13.1	58.7±4.2
FlowPolicy (Ours)	20.4±0.5	19.3±0.9	20.6±0.2	20.6±0.03	20.5±0.06	20.8±0.2	20.2±0.18	19.9±0.1

Methods \ Tasks	Metaworld (Easy)							
	Door Unlock	Drawer Close	Faucet Close	Faucet Open	Handle Press	Handle Pull	Lever Pull	Plate Slide
DP3	142.0± 0.9	155.4±0.5	141.2±0.2	142.5±0.7	145.8±1.1	146.1±0.7	141.1±2.4	145±3.3
Simple DP3	64.9±10.3	55.1±2.5	62.4±8.6	60.3±1.4	58.1±4.6	67.3±6.7	60.5±4.0	65.7±2.8
FlowPolicy (Ours)	20.1±0.07	18.0±0.03	20.0±0.05	20.3±0.05	20.5±0.48	19.2±0.7	20.6±0.8	20.0±0.2

Methods \ Tasks	Metaworld (Easy)						
	Plate Slide Back	Plate Slide Back Side	Plate Slide Side	Reach	Reach Wall	Window Close	Window Open
DP3	146.0±2.7	151.4±0.7	145.7±3.3	146.4±2.1	146.4±3.0	148.1±2.7	143.8±2.8
Simple DP3	64.7±9.0	67.1±4.9	60.4±10.7	57.6±2.2	65.3±7.0	62.6±9.5	59.3±5.6
FlowPolicy (Ours)	19.8±0.04	18.1±0.01	20.0±0.04	20.4±0.02	20.1±0.06	19.9±0.02	20.0±0.02

Methods \ Tasks	Metaworld (Easy)	Metaworld (Medium)				Metaworld (Hard)	
	Peg Unplug Side	Coffee Pull	Hammer	Peg Insert Side	Soccer	Assembly	Hand Insert
DP3	144.7±2.2	148.0±2.4	141.6±2.4	146.6±3.2	142.9±1.3	150.3±6.6	143.3±3.3
Simple DP3	61.1±9.0	56.2±2.2	56.2±2.9	67.2±7.6	58.2±3.7	64.2±1.7	63±9.0
FlowPolicy (Ours)	20.1±0.18	18.1±0.07	20.8±0.5	20.8±0.6	19.8±0.08	20.0±0.2	19.8±0.07

Methods \ Tasks	Metaworld (Hard)		Metaworld (Very Hard)					**Average**
	Pick Place	Push	Shelf Place	Disassemble	Stick Pull	Stick Push	Pick Place Wall	
DP3	149.6±3.3	151.3±0.7	142.5±2.2	143.3±2.4	142.3±1.5	145.0±6.4	142.9±0.8	145.7±2.3
Simple DP3	65.0±7.3	59.8±9.4	55.7±1.5	66.4±6.9	62.8±3.4	70.1±6.6	71.5±15.3	63.0±5.9
FlowPolicy (Ours)	20.1±0.2	20.5±0.5	19.8±0.07	19.8±0.1	19.9±0.09	20.5±0.4	20.1±0.2	**19.9±0.2**

Table S3: Complete results for runtime. We report in detail the average runtime of DP3 (Ze et al. 2024) and our FlowPolicy for each task.

Methods \ Tasks	Adroit			Metaworld (Easy)				
	Hammer	Door	Pen	Button Press	Button Press Wall	Dial Turn	Door Close	Door Open
DP3 (one-step)	98±2	48±7	31±7	100±0	91±7	26±11	100±0	100±0
FlowPolicy (Ours)	100±0	58±5	53±12	100±0	100±0	63±4	100±0	100±0

Methods \ Tasks	Metaworld (Easy)							
	Door Unlock	Drawer Close	Faucet Close	Faucet Open	Handle Press	Handle Pull	Lever Pull	Plate Slide
DP3 (one-step)	100±0	100±0	98±2	96±2	96±4	23±8	61±8	93±4
FlowPolicy (Ours)	100±0	100±0	100±0	100±0	100±0	40±7	63±17	91± 7

Methods \ Tasks	Metaworld (Easy)						
	Plate Slide Back	Plate Slide Back Side	Plate Slide Side	Reach	Reach Wall	Window Close	Window Open
DP3 (one-step)	100±0	100±0	100±0	56±5	48±12	100±0	100±0
FlowPolicy (Ours)	100±0	100±0	100±0	80±9	83±8	100±0	100±0

Methods \ Tasks	Metaworld (Easy)	Metaworld (Medium)				Metaworld (Hard)	
	Peg Unplug Side	Coffee Pull	Hammer	Peg Insert Side	Soccer	Assembly	Hand Insert
DP3 (one-step)	61±10	53±8	75±3	8±2	6±4	71±5	11±5
FlowPolicy (Ours)	76±7	55±14	95±3	20±8	20±6	85±6	23±7

Methods \ Tasks	Metaworld (Hard)		Metaworld (Very Hard)					**Average**
	Pick Place	Push	Shelf Place	Disassemble	Stick Pull	Stick Push	Pick Place Wall	
DP3 (one-step)	5±3	15±3	3±2	61±10	8±5	53±4	16±4	62.7±4.2
FlowPolicy (Ours)	25±6	16±10	5±3	50±15	35±12	68±2	25±6	**70.0±4.7**

Table S4: Quantitative comparisons of success rate with one-step inference. We report detailed success rate results for DP3 (Ze et al. 2024) and our FlowPolicy for each task in detail.