HITL-D: Human In The Loop Diffusion Assisted Shared Control

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Motivation

Background:

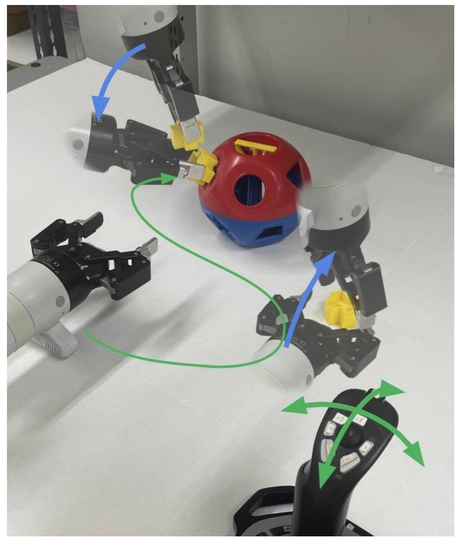
- Impaired individuals **struggle with mental workload** controlling WMRAs
- Shared control often has control authority or **aims to infer users intent**

Goal:

- **Reduce mental workload** while **maintaining user independence**
- Keep the **user in authority** at all times with **no intent estimation**

We propose **HITL-D**, a shared control paradigm involving generative diffusion policies, and deploy it in a **WMRA setting for impaired individuals**

Shared Control Pipeline

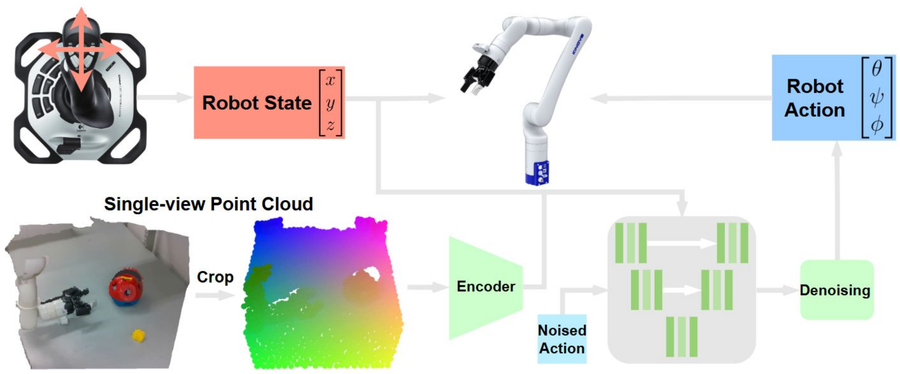


- User operates a **2 DoF joystick** and controls the **end effector translations (x, y, z)** by leaning the stick left/right for x, forward/backward for y and pushing the thumb button forward or backward for z.
- Diffusion policy generates **absolute end effector orientations**
- Using a **proportional controller**, we orient quickly in big differences and slowly in small differences, creating a **smooth convergent behavior**

Reactive Control:

- **Action horizon of 1** rather than commonly used 16 for generative policies. We propose an action horizon of 1 **due to users unpredictability** of movement as well as removing any guidance **keeping user authority**.

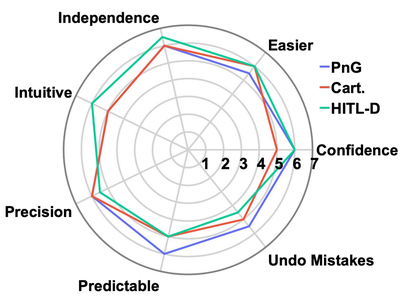
HITL-D Methods



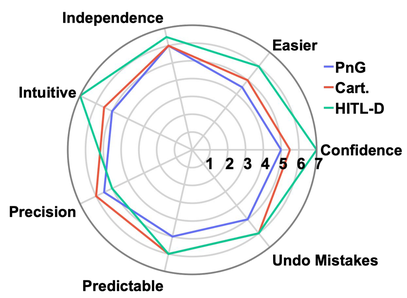
- Pointcloud is **cropped** and downsampled to **1024 points using FPS**
- Using a simple **3 layer MLP** we **encode the pointcloud** to a 64 dimension array
- **Condition** our **diffusion policy** on encoded **pointcloud and EE position**
- Action is an **absolute EE orientation**

User Study Results

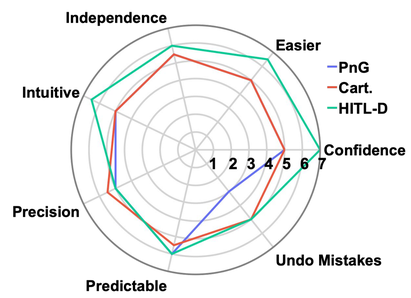
Unstack



Screwdriver



Shape Matching



Experiment \ Metric	Completion Time (s)			NASA-TLX Workload (/100)			Resets (#/Trial)			Success Rate (%)		
	HITL-D	PnG	Cart.	HITL-D	PnG	Cart.	HITL-D	PnG	Cart.	HITL-D	PnG	Cart.
Unstack	**95.5±7.1**	110.4±8.0	124.2±9.9	**32.5±4.8**	42.1±5.9	43.8±3.8	0.11±0.09	0.06±0.04	0.28±0.09	100.0	91.7	86.1
Screwdriver	**36.5±5.8**	88.1±9.5	72.9±9.3	**25.5±3.4**	53.6±5.2	42.1±6.4	0.22±0.11	0.22±0.09	0.17±0.08	100.0	94.4	97.2
Shape Match	**56.7±6.7**	126.1±7.0	96.9±7.7	**32.0±6.0**	57.6±6.1	52.5±7.2	0.33±0.10	0.44±0.09	0.25±0.10	97.2	77.8	97.2
Overall	**62.9±19.1**	108.2±21.1	98.0±17.4	**30.0±14.5**	51.1±16.4	46.1±13.8	0.22±0.25	0.24±0.16	0.23±0.24	99.1	88.0	93.5

[1] Results are reported with standard error. Bold = Shared significantly better than Point and Go; Underline = Shared significantly better than Cartesian.