

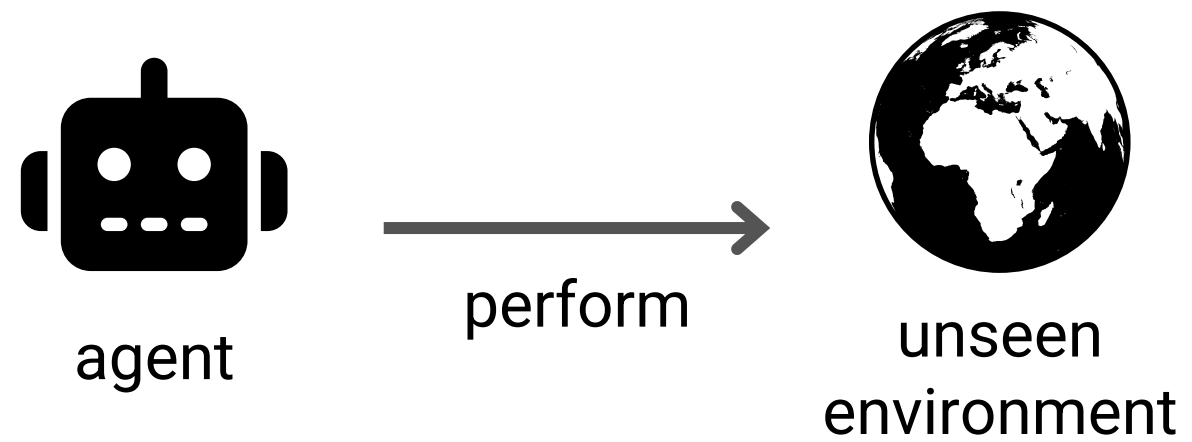


AED: Adaptable Error Detection for Few-shot Imitation Policy

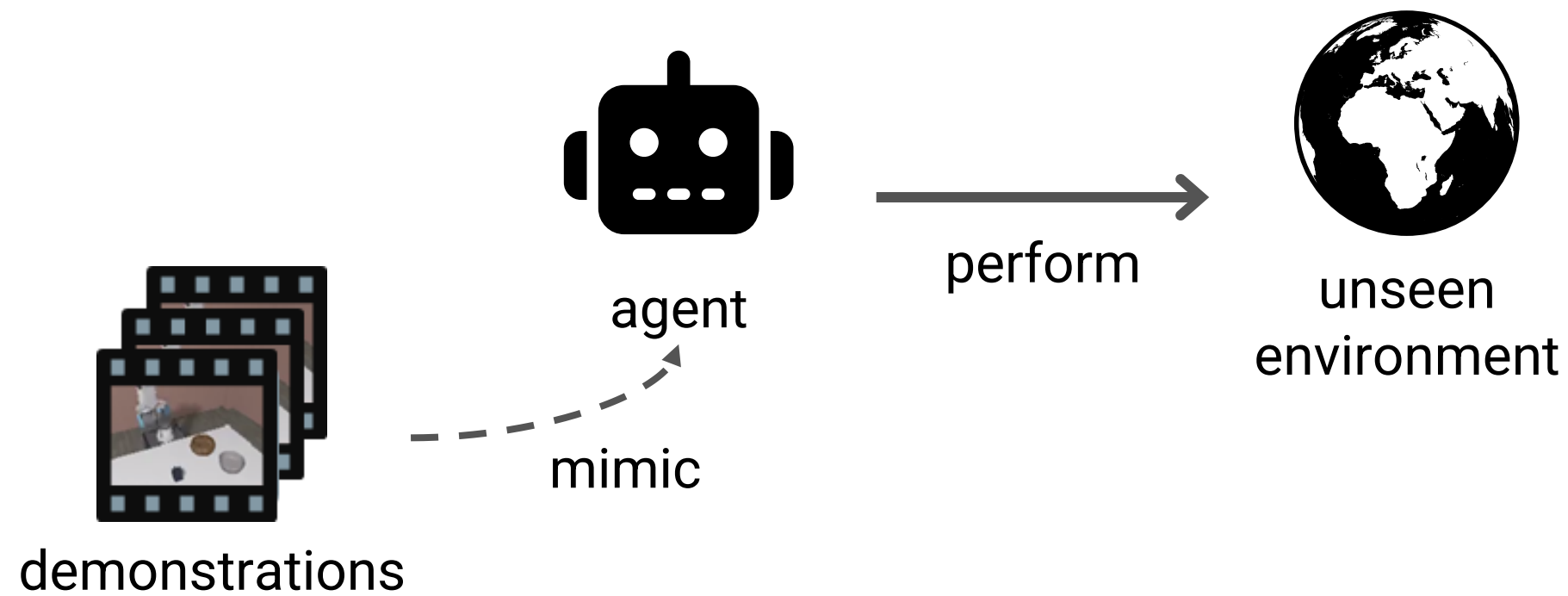
Jia-Fong Yeh Kuo-Han Hung Pang-Chi Lo Chi-Ming Chung Tsung-Han Wu
Hung-Ting Su Yi-Ting Chen Winston H Hsu



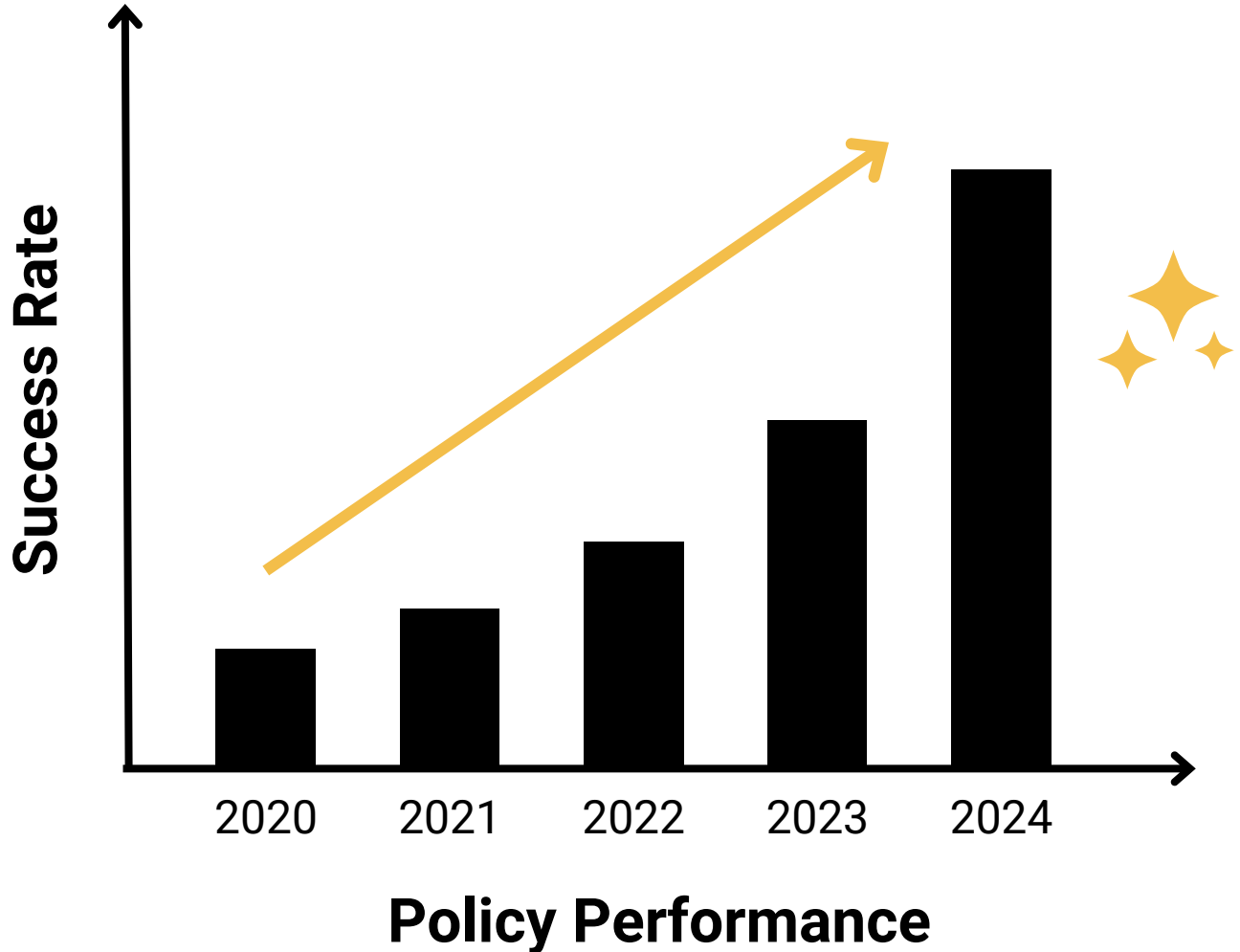
Few-shot imitation (**FSI**) policy learns to perform tasks in **novel (unseen) environments**



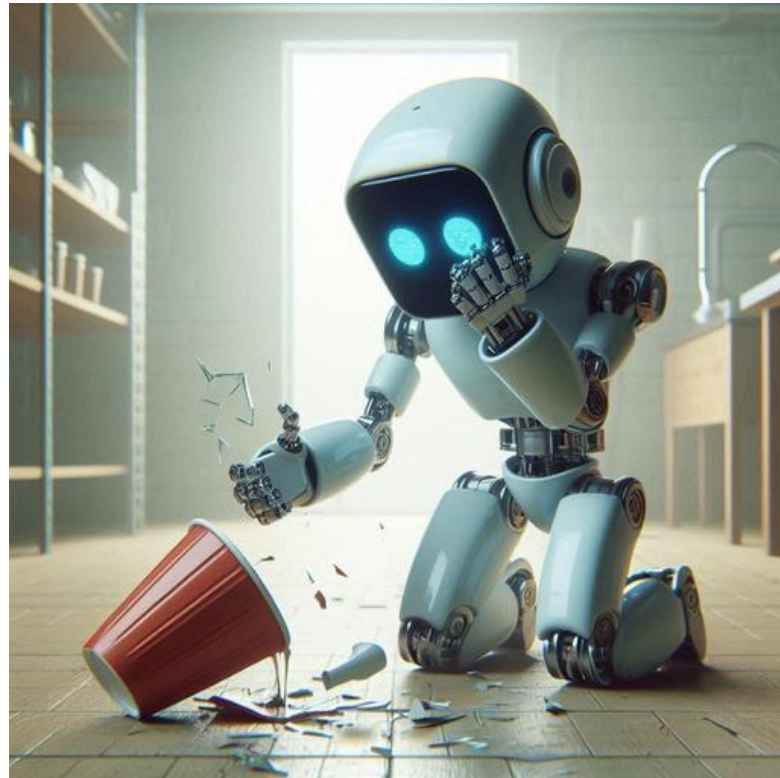
Few-shot imitation (**FSI**) policy learns to perform tasks in **novel (unseen) environments** by observing only a **few demonstrations**



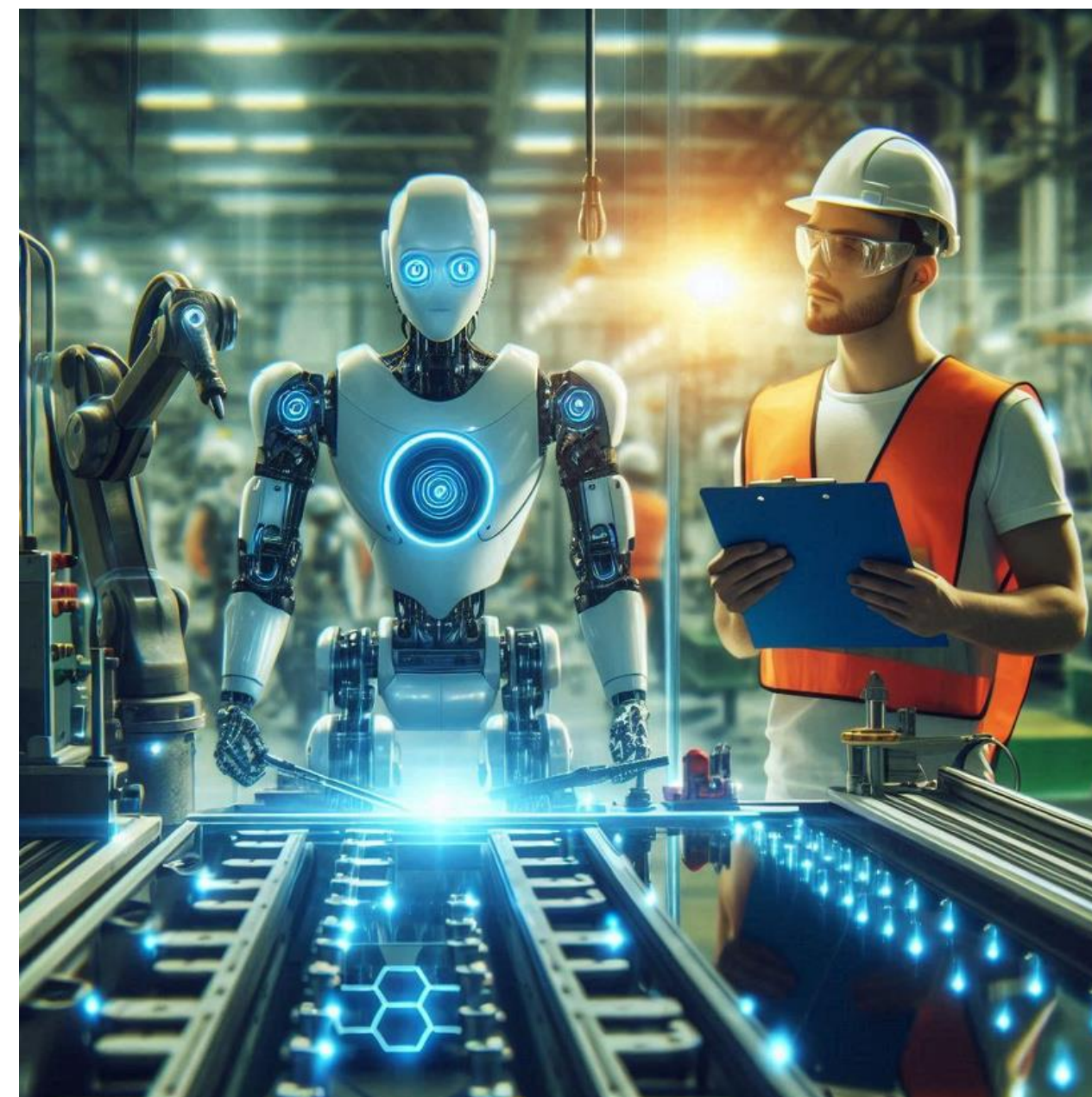
State-of-the-art FSI policies achieve promising results across various tasks



However, the potential to **cause serious damage** to surrounding areas **significantly limits** their real-world applications



An **inspector** is required to **oversee the entire process** during agent deployment



Unfortunately, the requirement for **human inspectors** can be costly and is sometimes even **impossible**



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Adaptable **Error Detection**

A new learning paradigm for identifying the **erroneous behaviors** in FSI policies

A new learning paradigm for identifying the **erroneous behaviors** in FSI policies

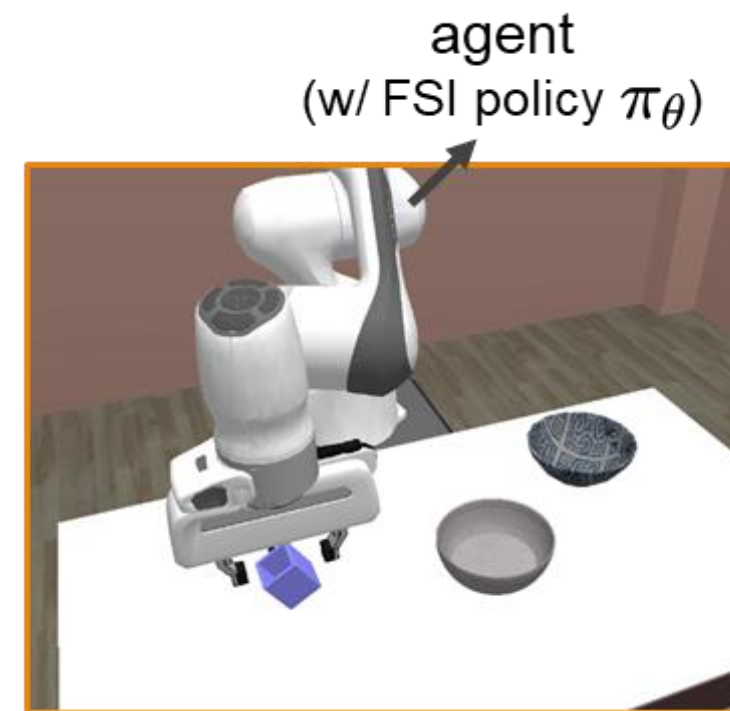


adaptable
error detector

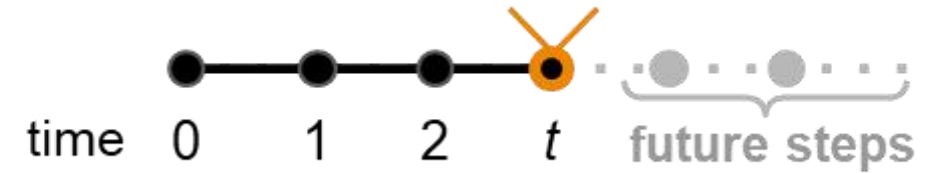
A new learning paradigm for identifying the **erroneous behaviors** in FSI policies



adaptable
error detector



current observation

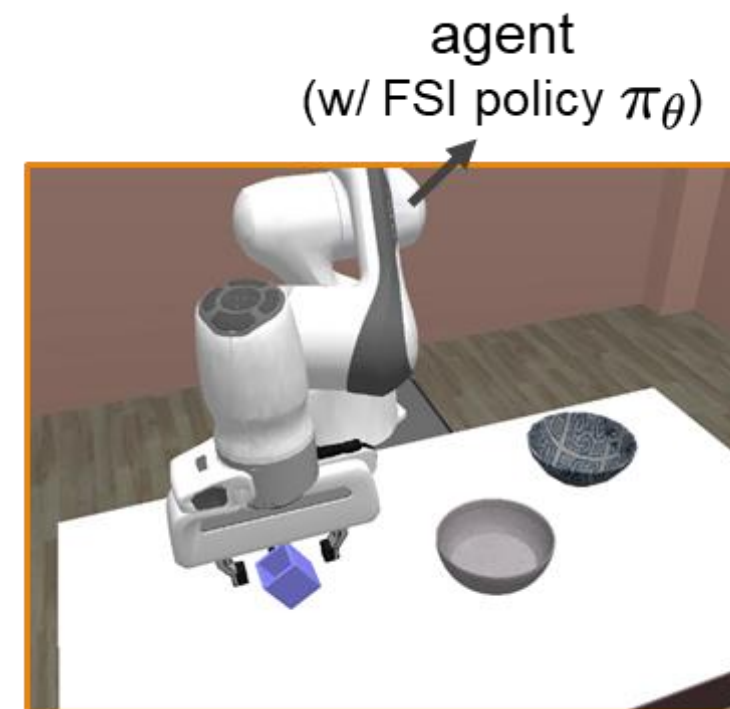


A new learning paradigm for identifying the **erroneous behaviors** in FSI policies

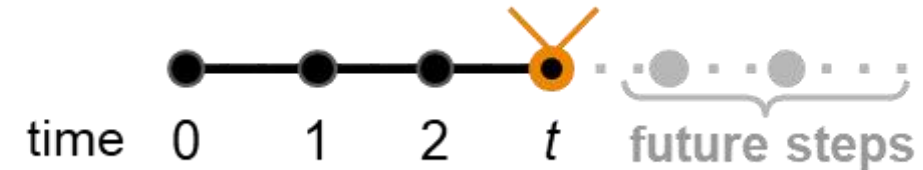


adaptable
error detector

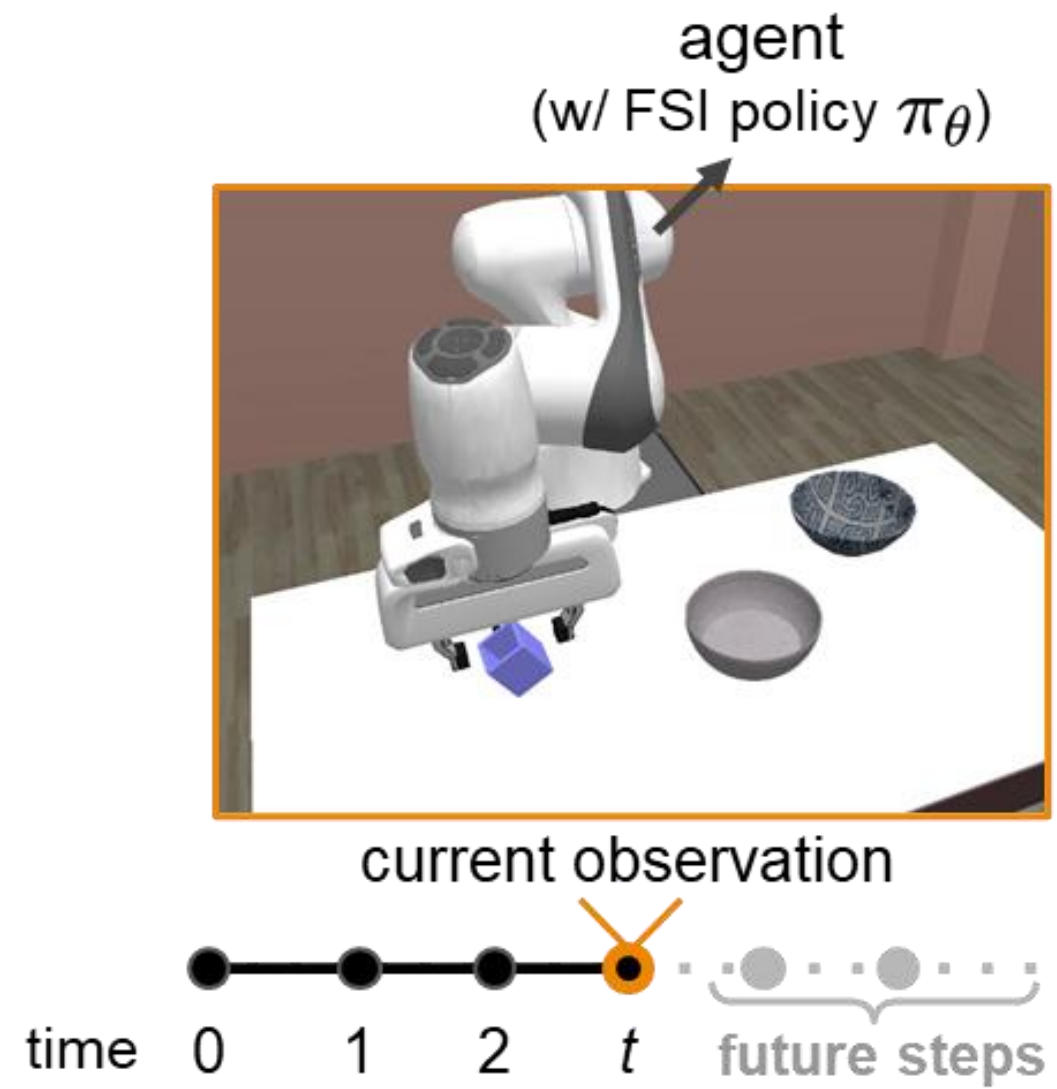
Alarm:
Pick failure



current observation

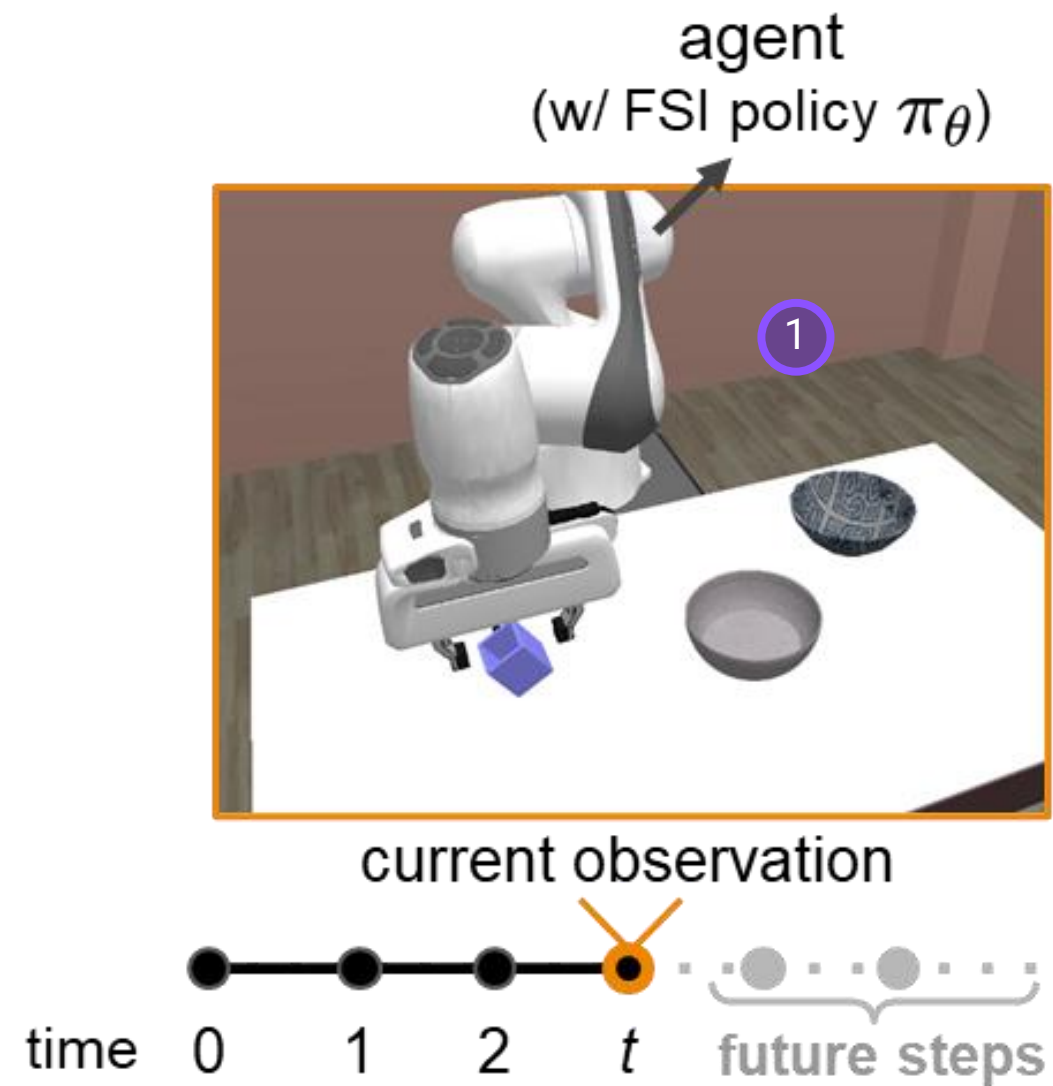


There are three unique challenges posed by our AED task:



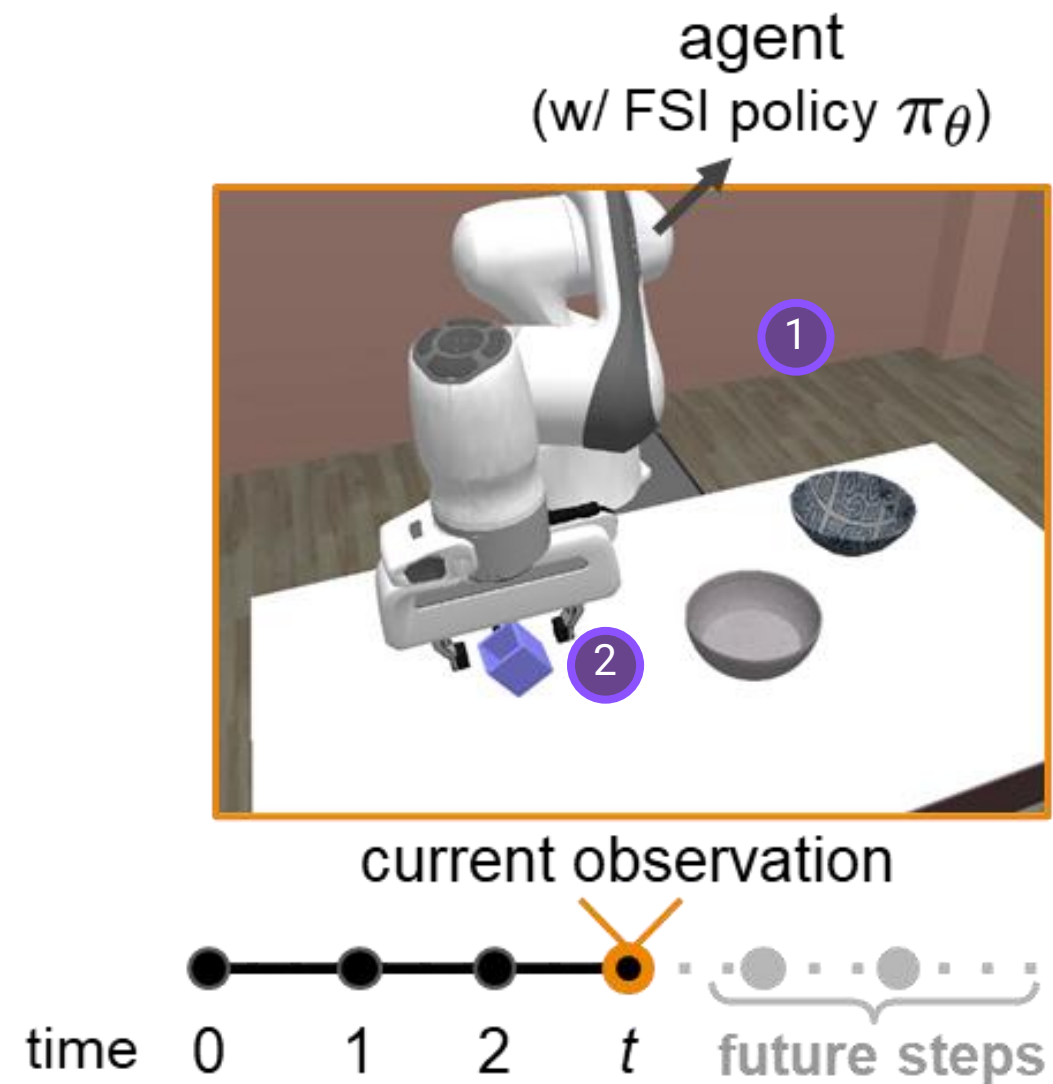
There are three unique challenges posed by our AED task:

1. Work in **novel environments**



There are three unique challenges posed by our AED task:

1. Work in **novel environments**
2. **No notable changes revealing** when behavior errors occur

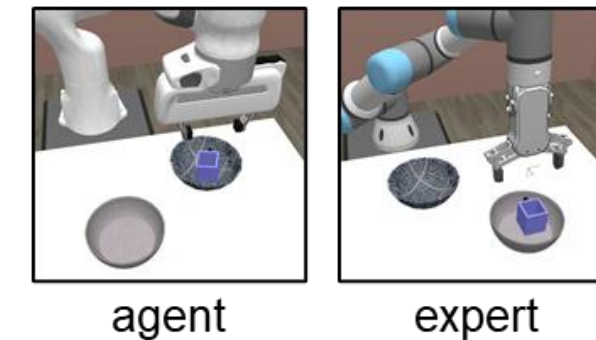
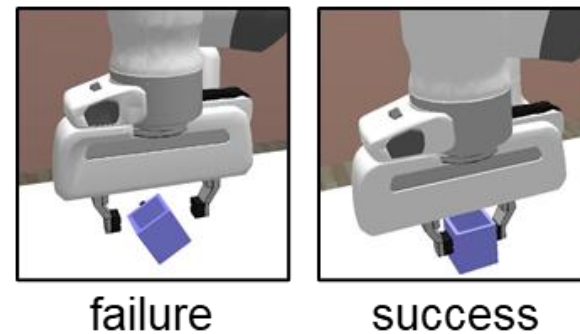
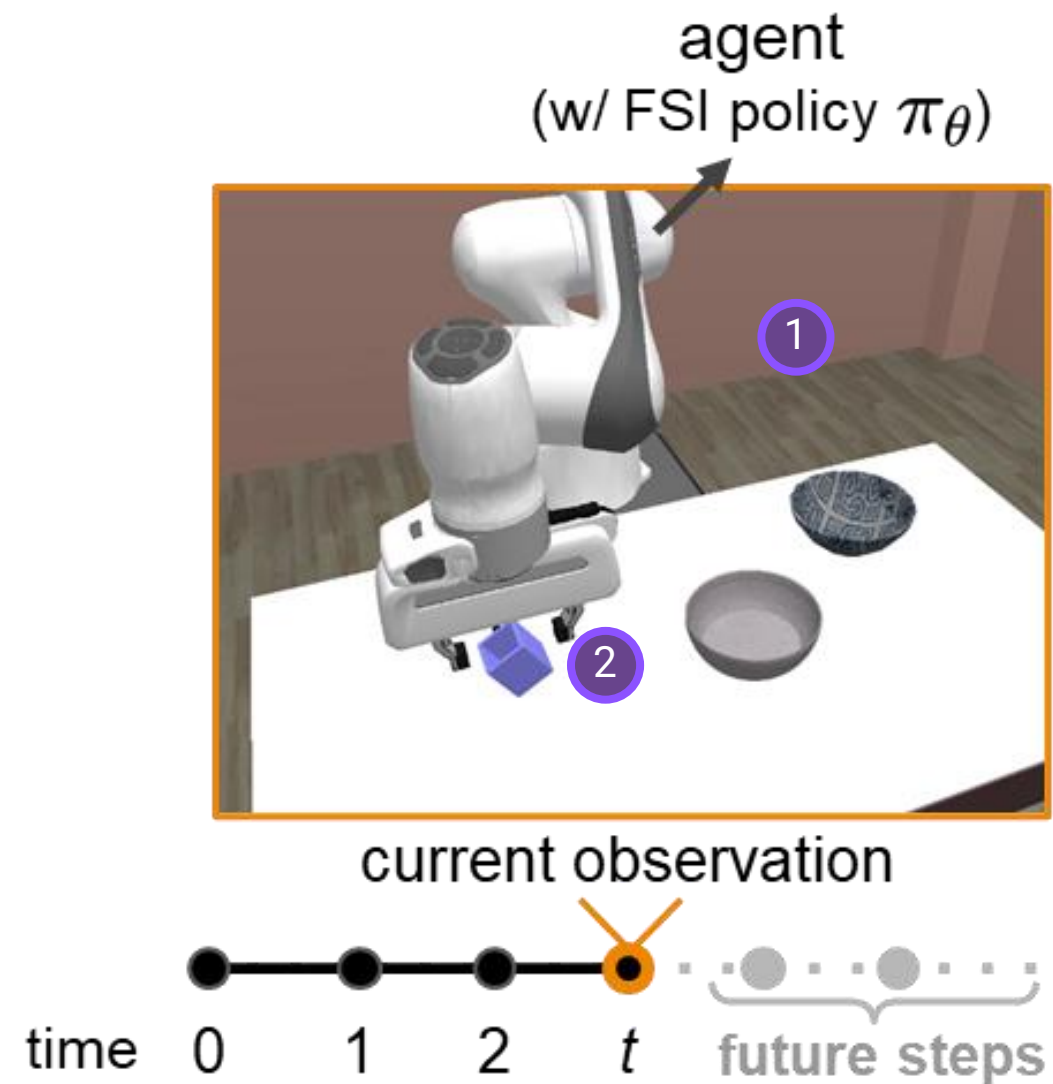


There are three unique challenges posed by our AED task:

1. Work in **novel environments**
2. **No notable changes revealing** when behavior errors occur

2-a. **minor** visual difference

2-b. task **misunderstanding**

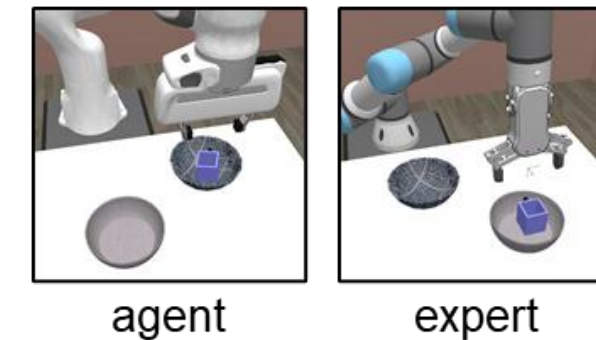
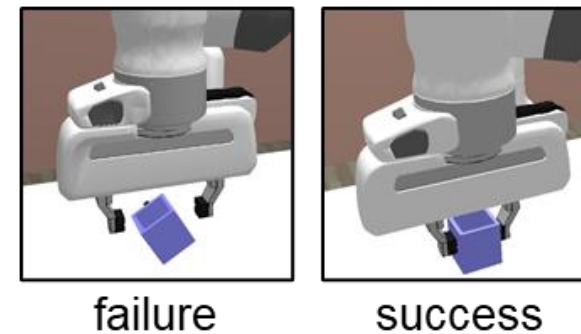
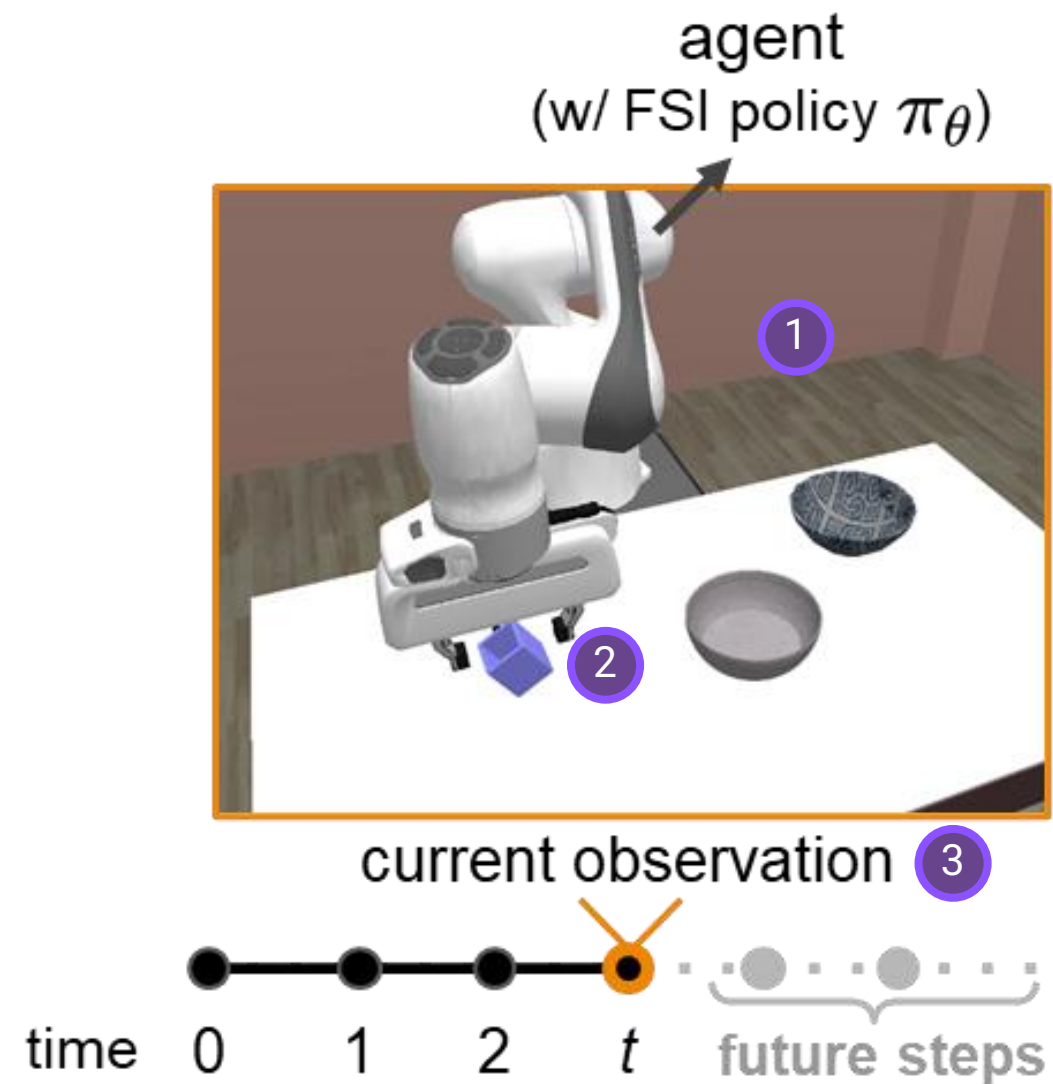


There are three unique challenges posed by our AED task:

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3. **Online** Detection

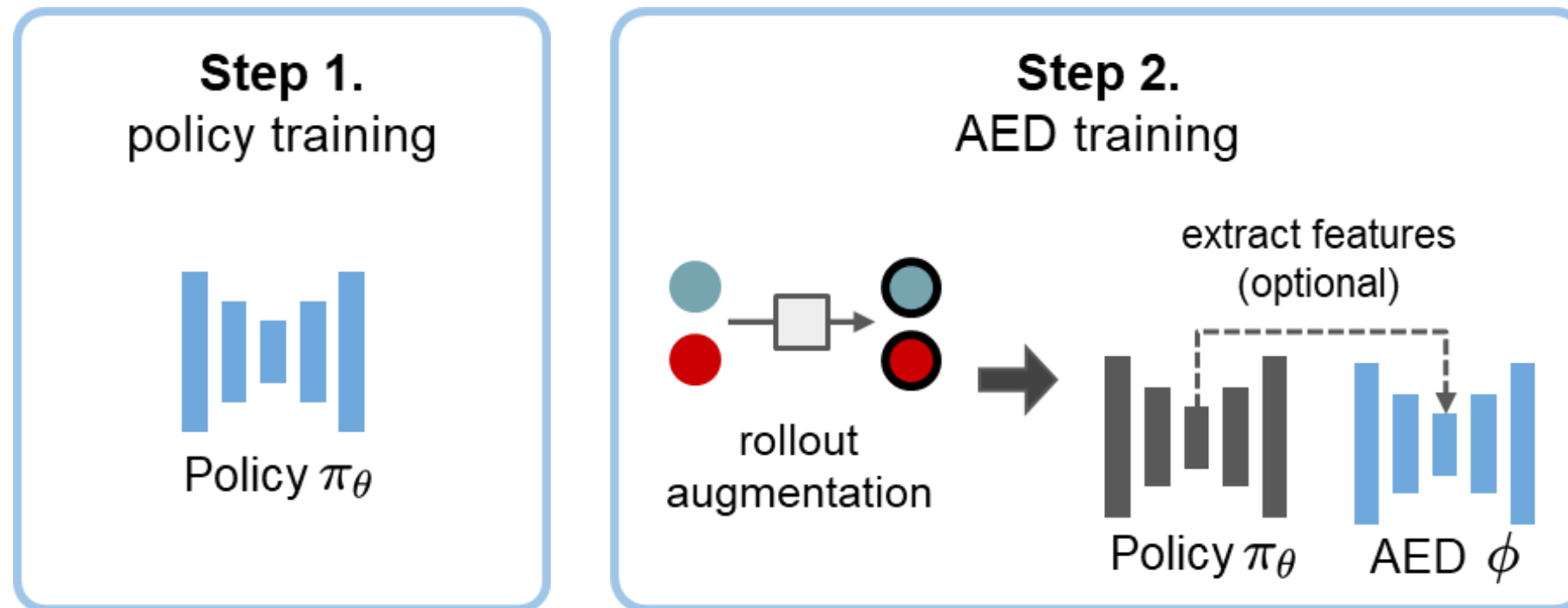
AED pipeline

Step 1.
policy training

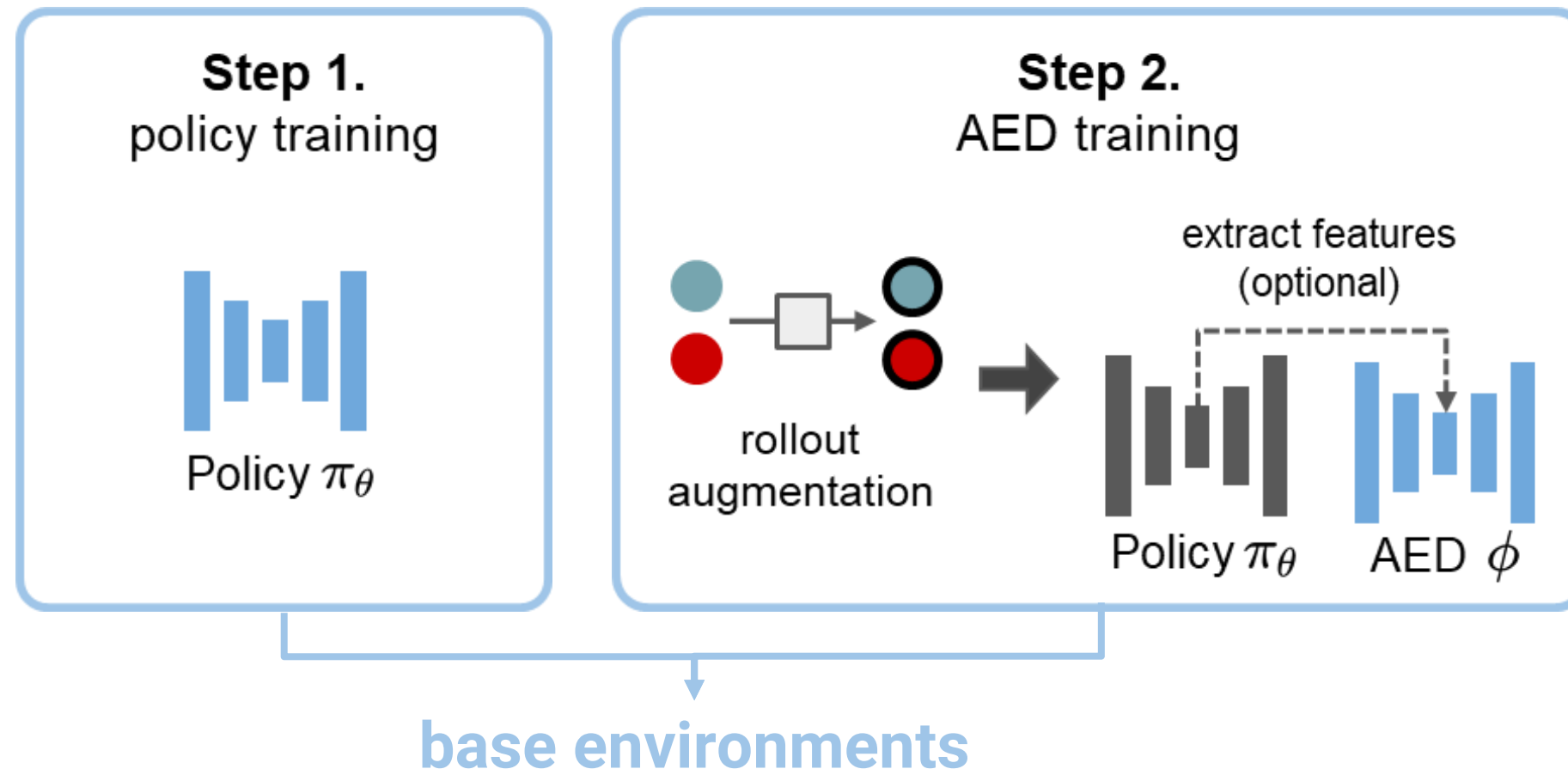


Policy π_θ

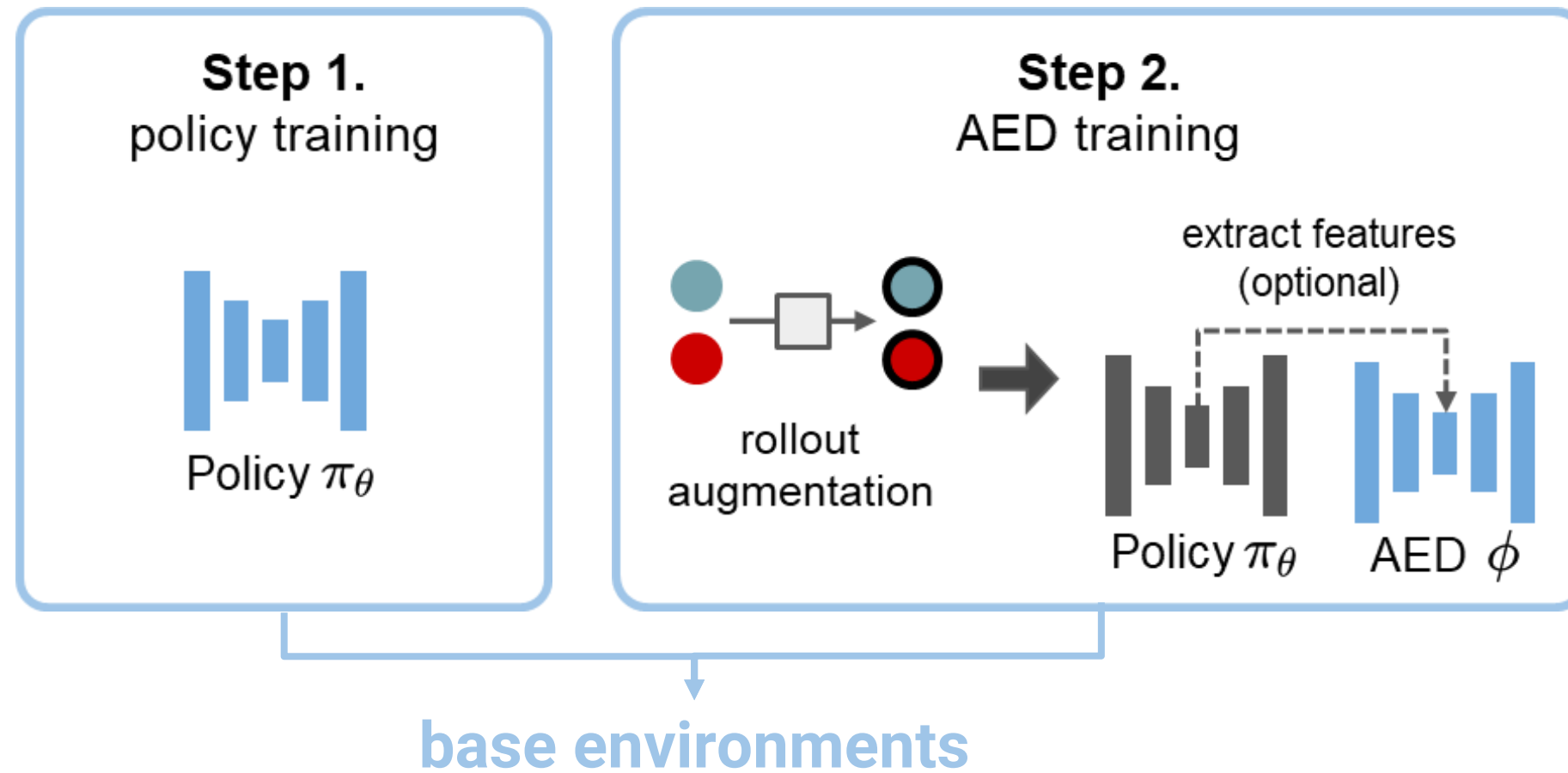
AED pipeline



AED pipeline

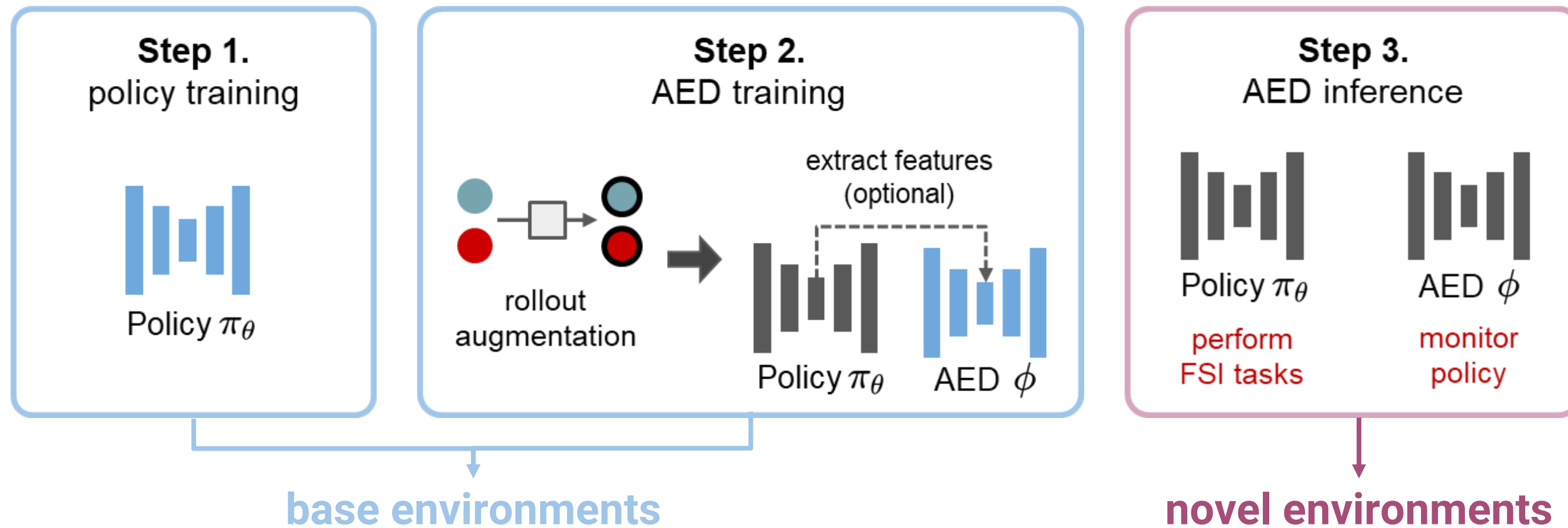


AED pipeline



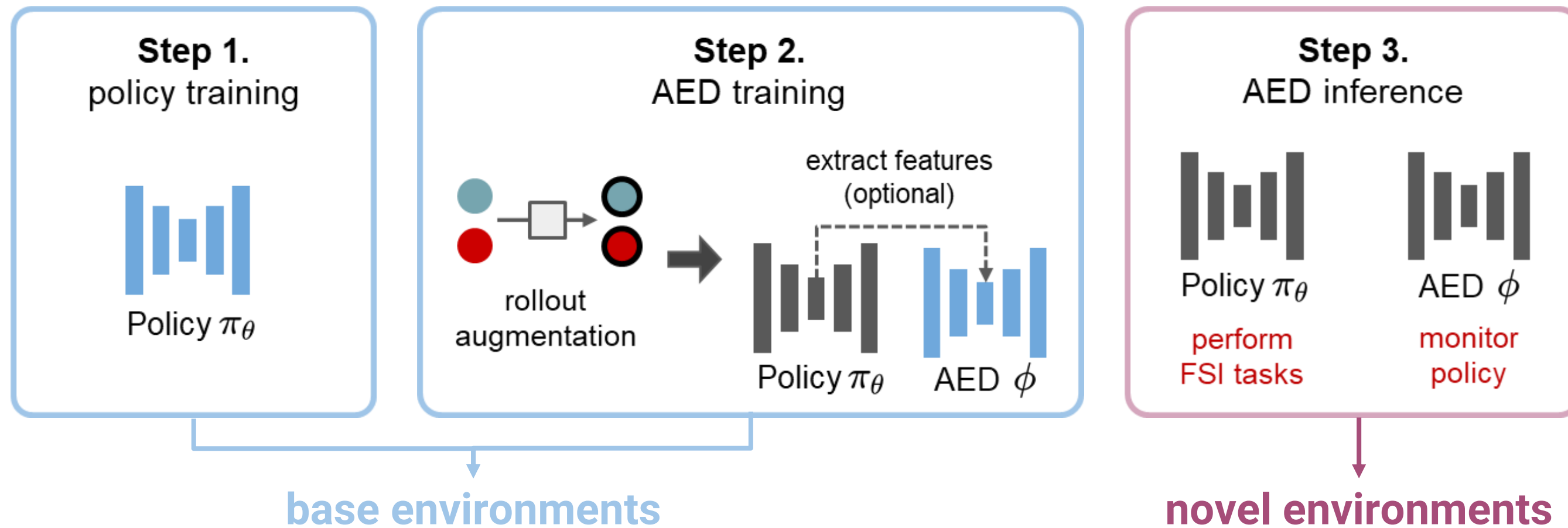
- a few demonstrations
- successful agent rollouts
- failed agent rollouts

AED pipeline



- a few demonstrations
- successful agent rollouts
- failed agent rollouts

AED pipeline



- a few demonstrations
- successful agent rollouts
- failed agent rollouts

- a few demonstrations

Within this pipeline, only a few demonstrations and the current rollout are available during agent deployment



adaptable
error detector

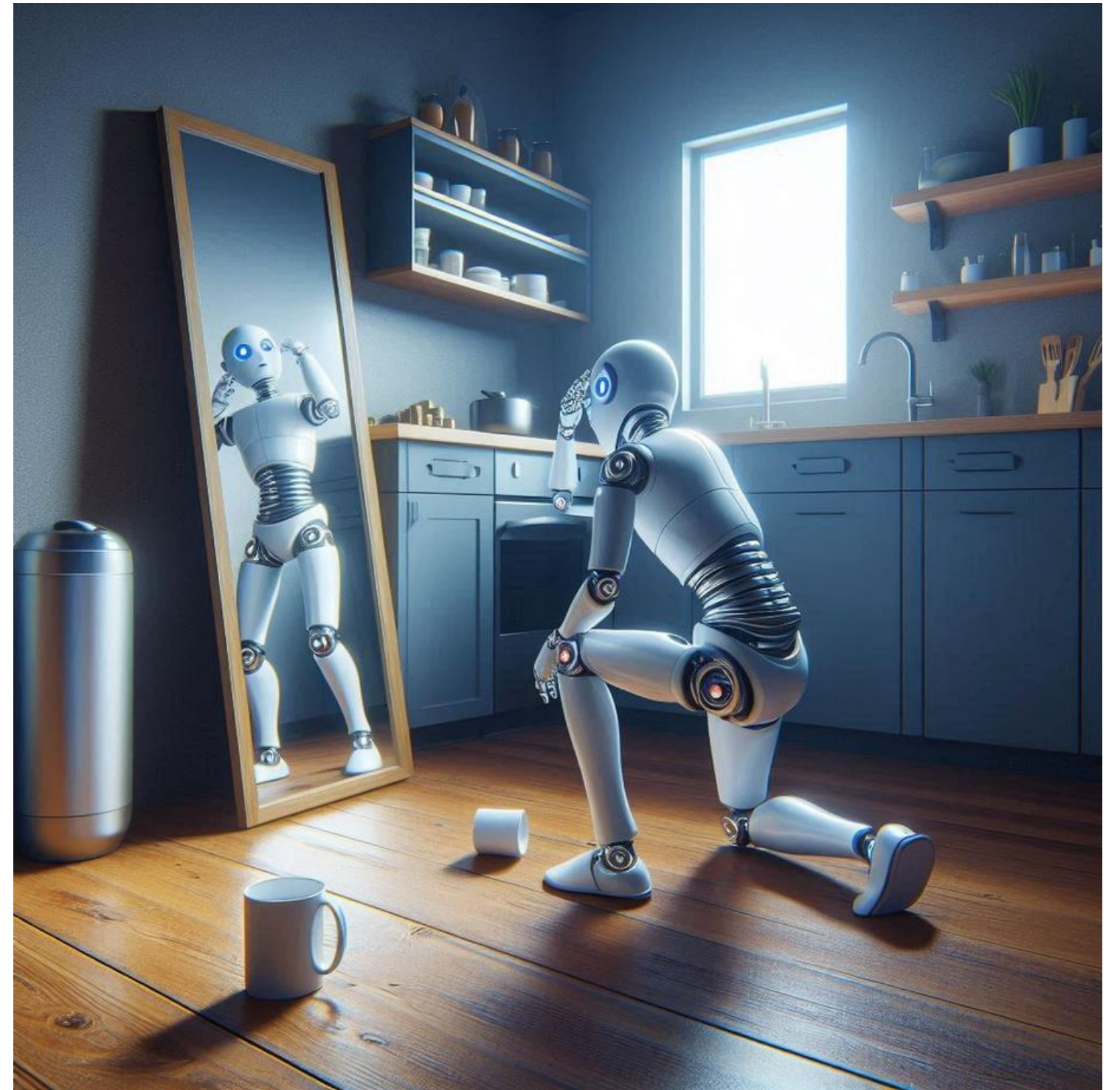


current rollout



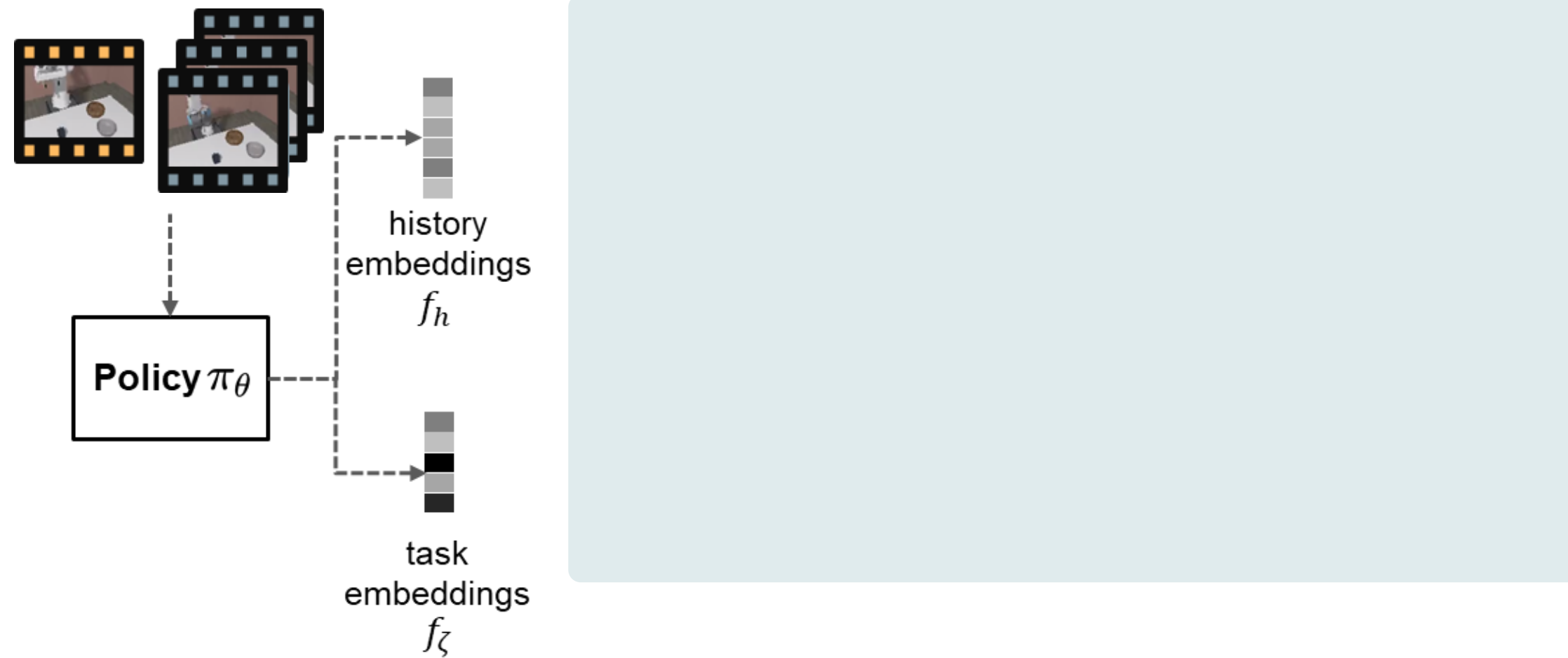
demonstrations

Question: Does the **policy itself** know that it is **deviating** from the **intent of the demonstration**?



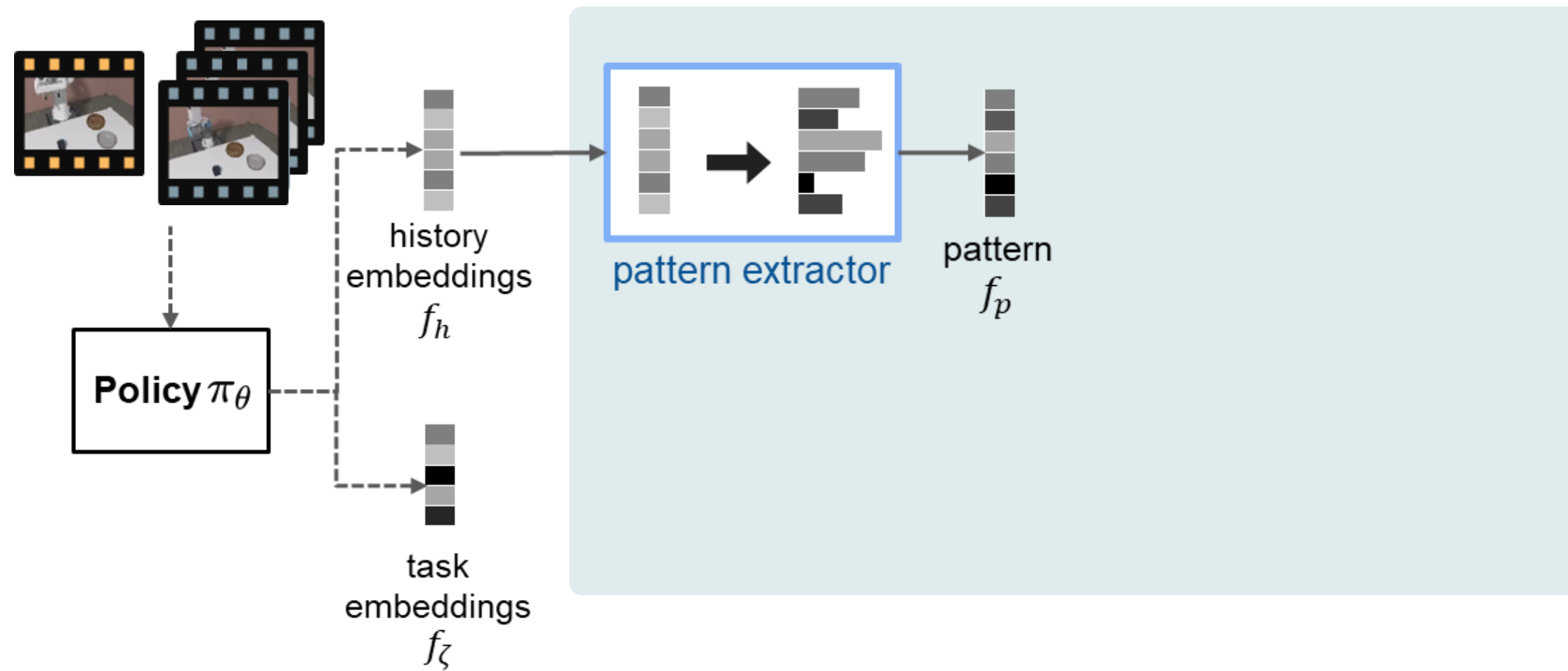
We propose **Pattern Observer (PrObe)**, a system for detecting erroneous behaviors by learning **discernible patterns** within the features extracted by policies, rather than relying on an independent encoder to learn from current observations

PrObe Architecture



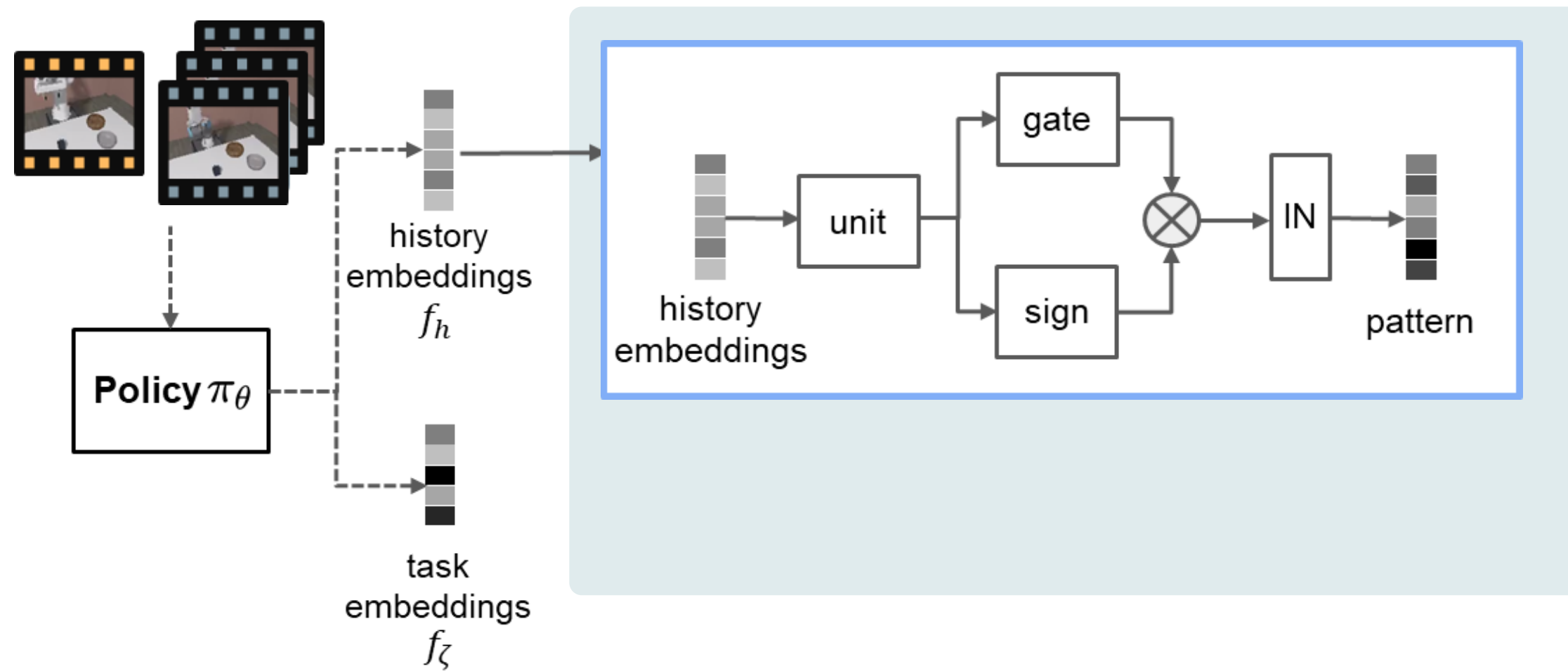
Get the features extracted from the policy

PrObe Architecture



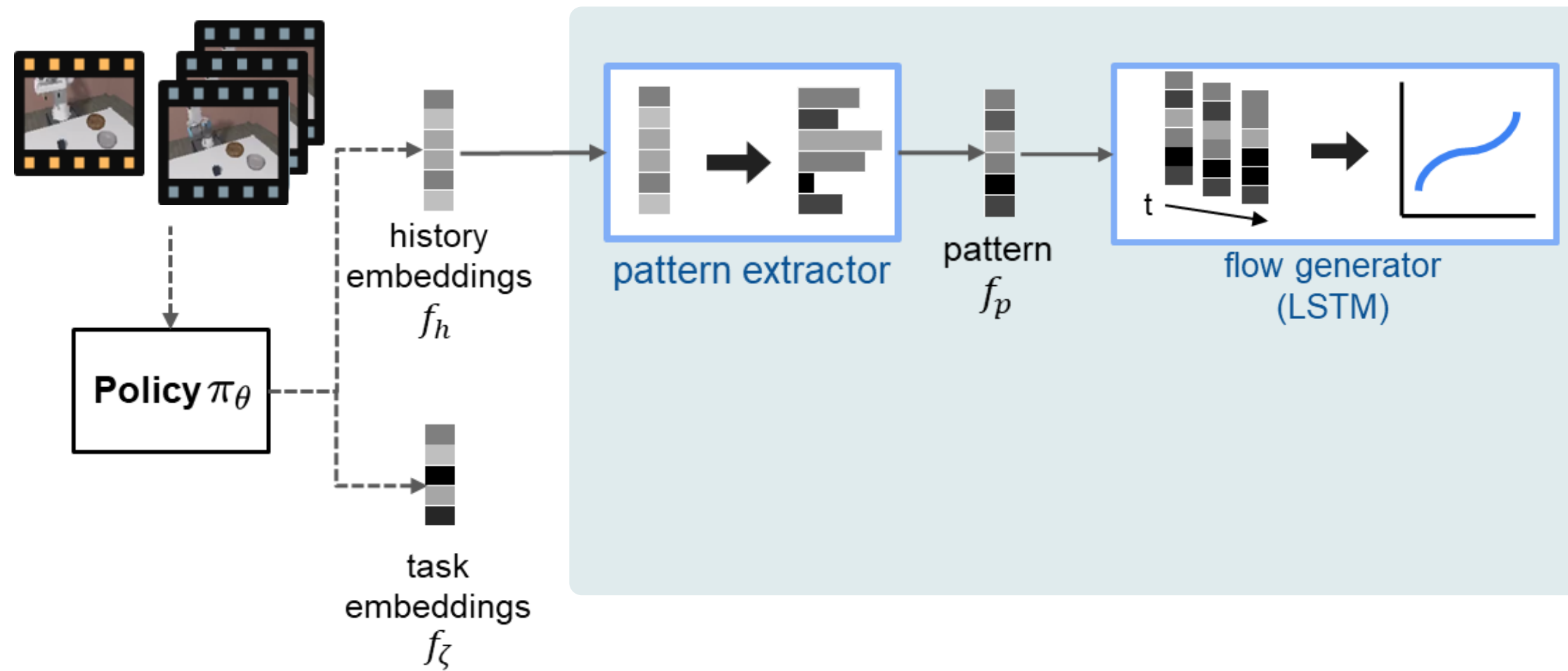
Assess the history embedding's importance scores as patterns

PrObe Architecture



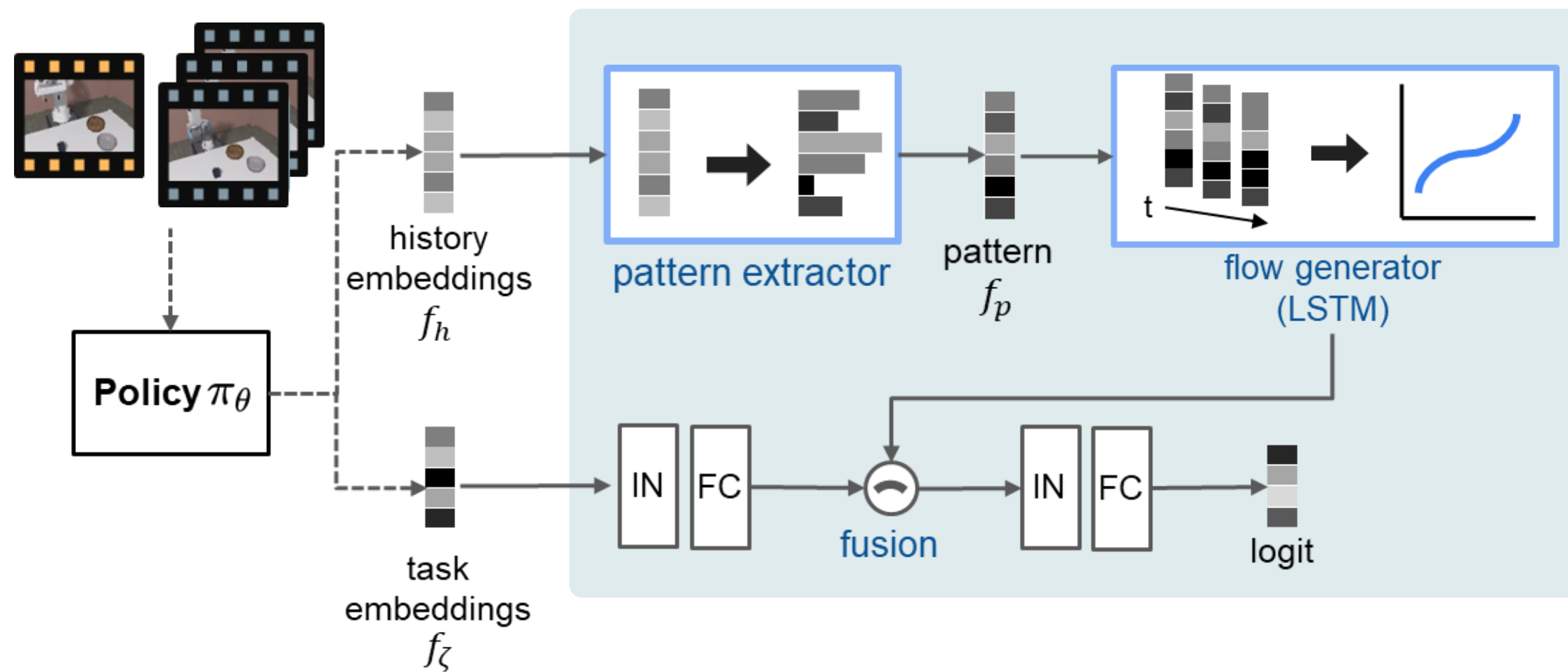
Pattern extractor is a learnable gating model
(For first challenge)

PrObe Architecture



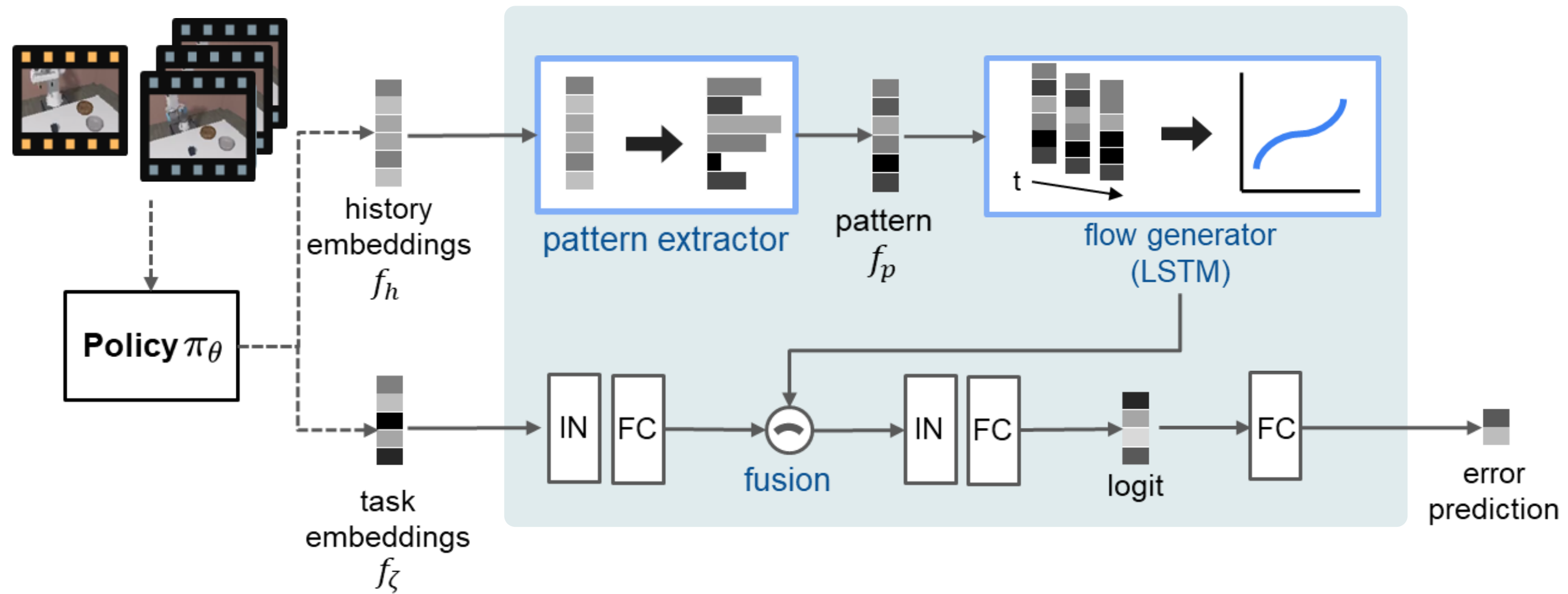
Pattern flows model the temporal information
(For third challenge)

PrObe Architecture



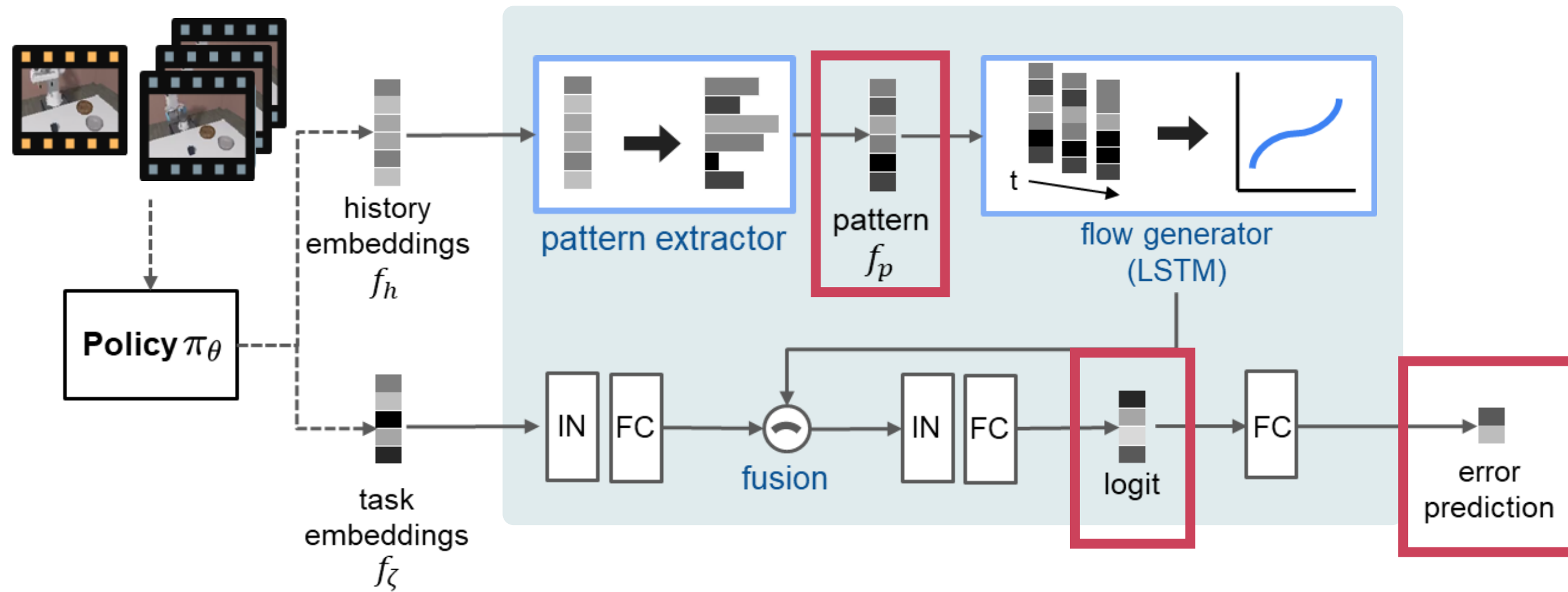
Apply the consistency comparison between pattern flow and the task-embeddings
(For second challenge)

PrObe Architecture



Output the final error prediction

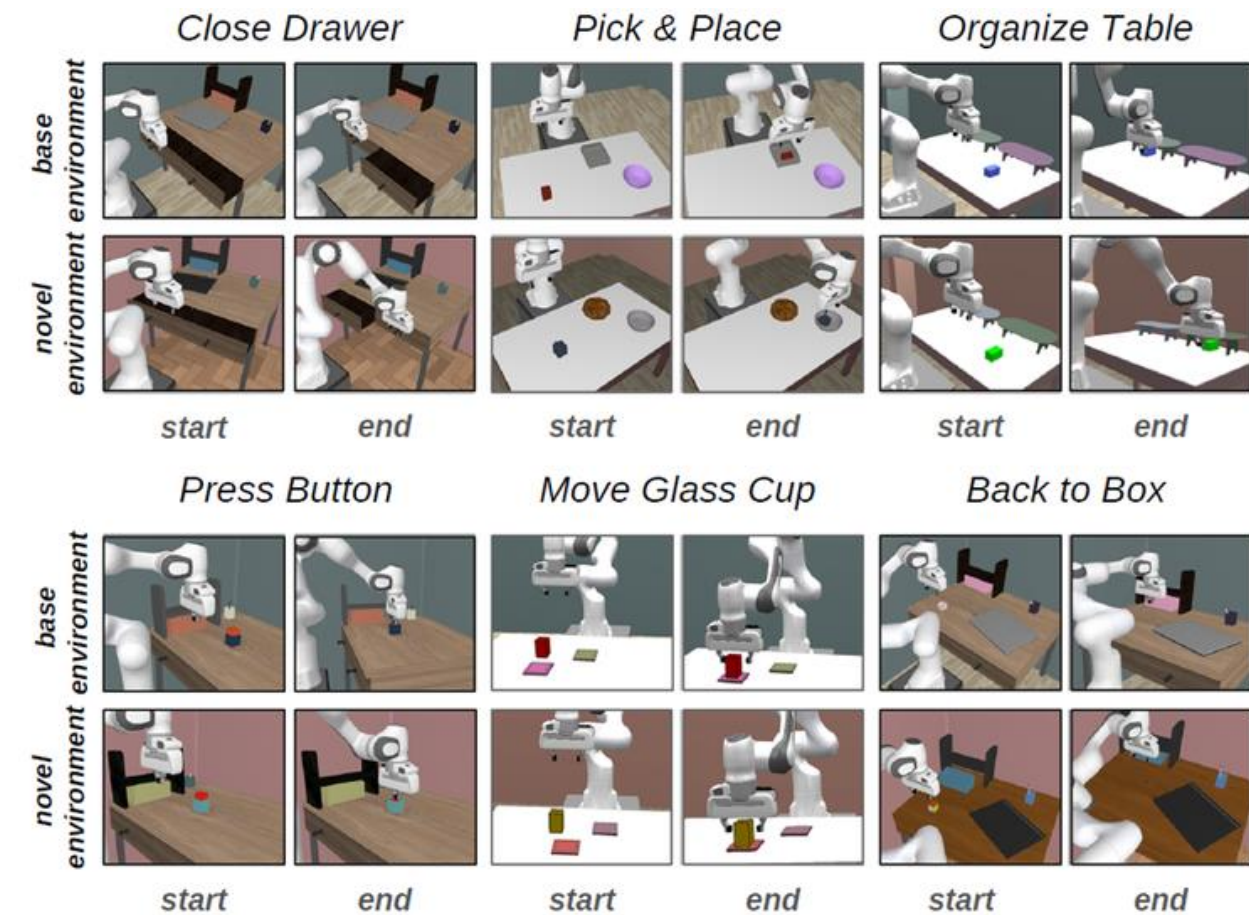
PrObe Architecture



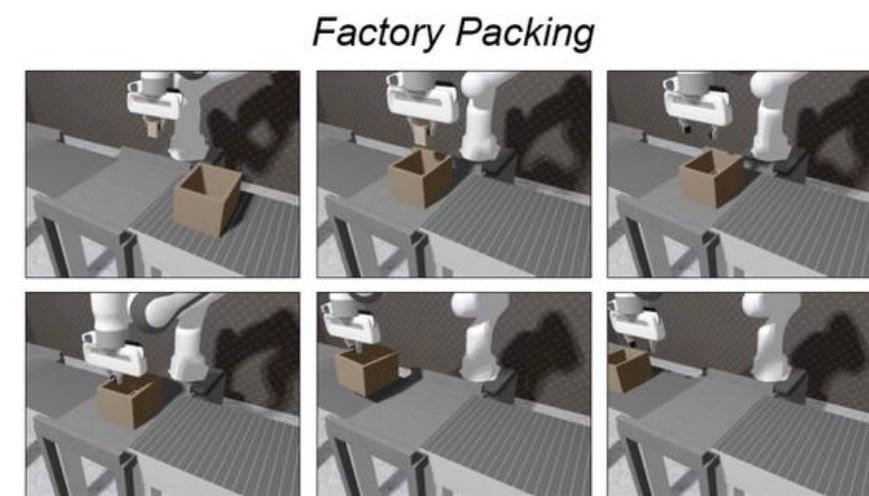
AED benchmark

- **Task**

- Seven FSI tasks (six indoor, one industrial)
- 322 base and 153 novel environments
- Attributes:
 - Multi-stage
 - Distracting objects
 - Multiple light sources and soft shadow
 - Gravity and friction



indoor scenes



industrial scene

AED benchmark

- **Evaluation Metrics**

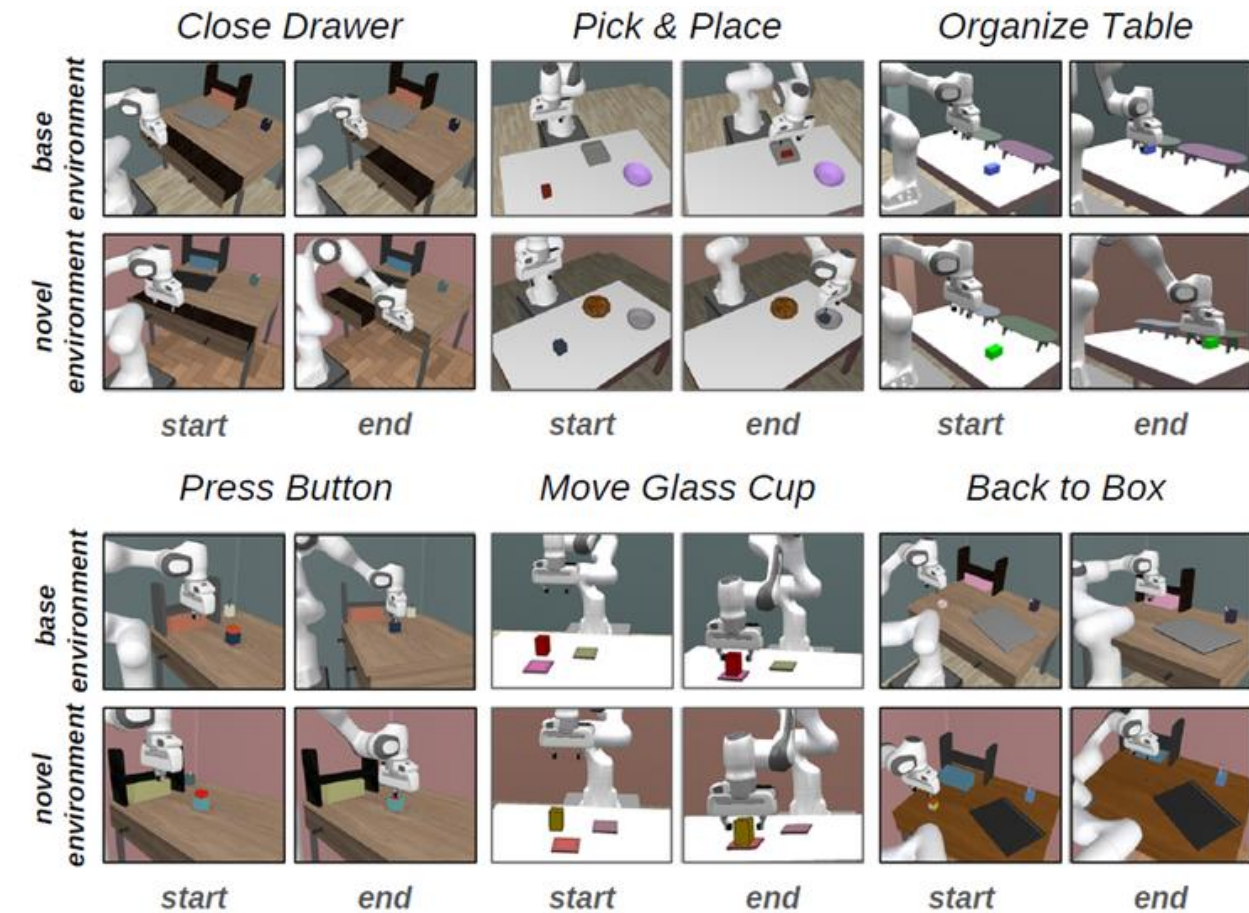
- AUROC
- AUPRC

- **FSI policies**

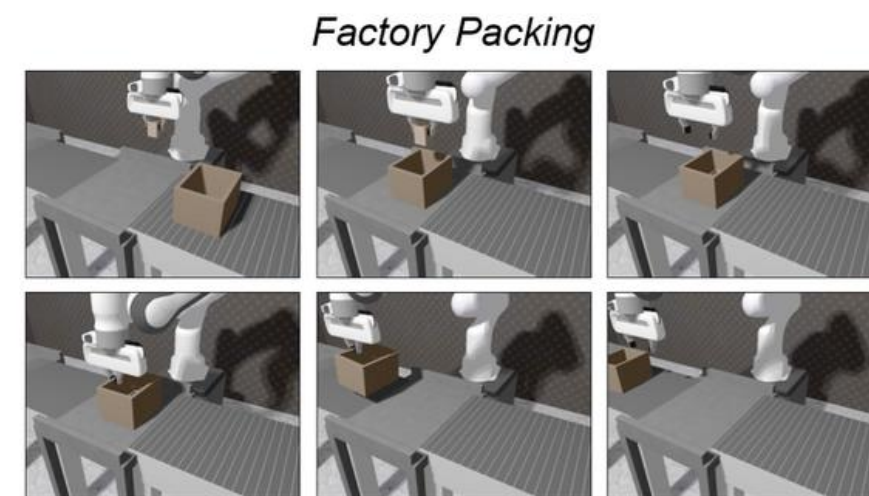
- NaiveDC (CoRL'18)
- SCAN (AAAI'22)
- DCT (ICML'21)

- **Error Detection Baselines**

- SVDDDED (one-class SVM, ICML'18)
- TaskEmbED (metric learning, CoRL'18)
- LSTMED (classical RNN)
- DCTED (transformer, ICML'21)

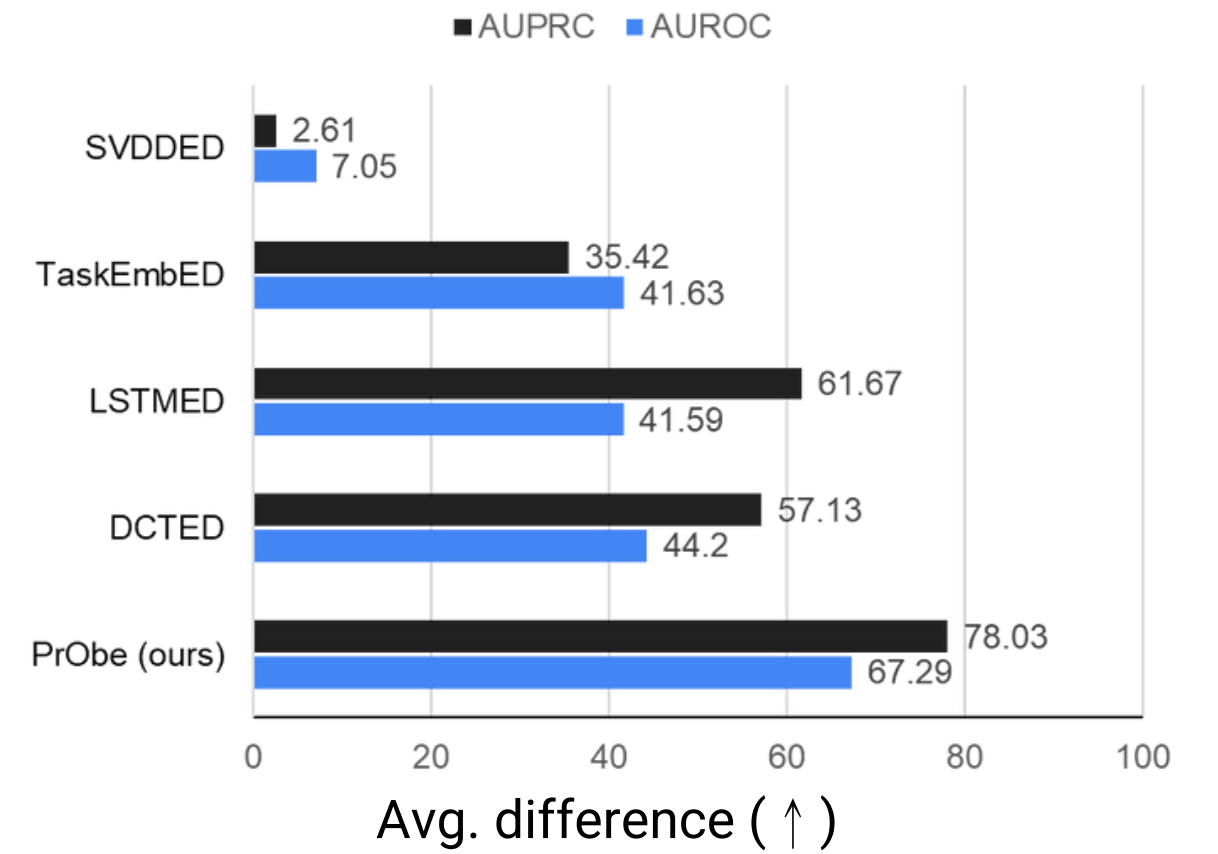
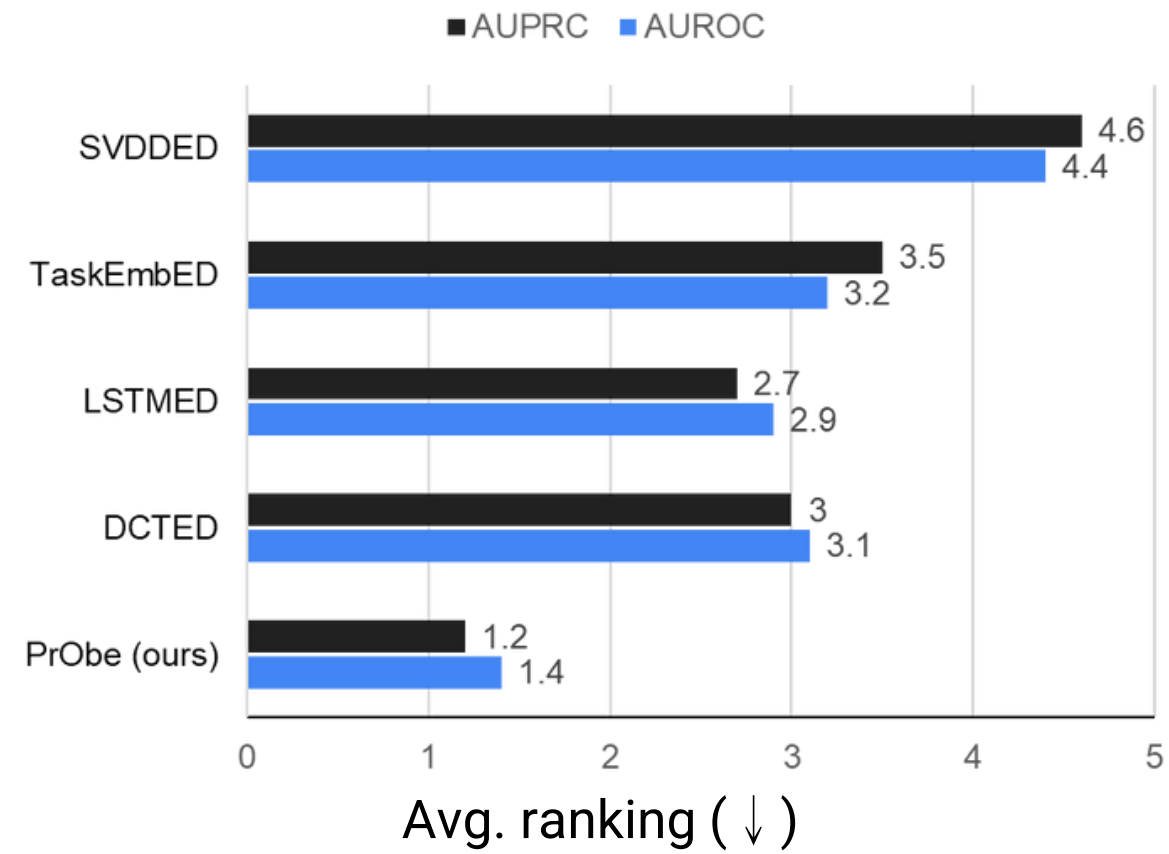
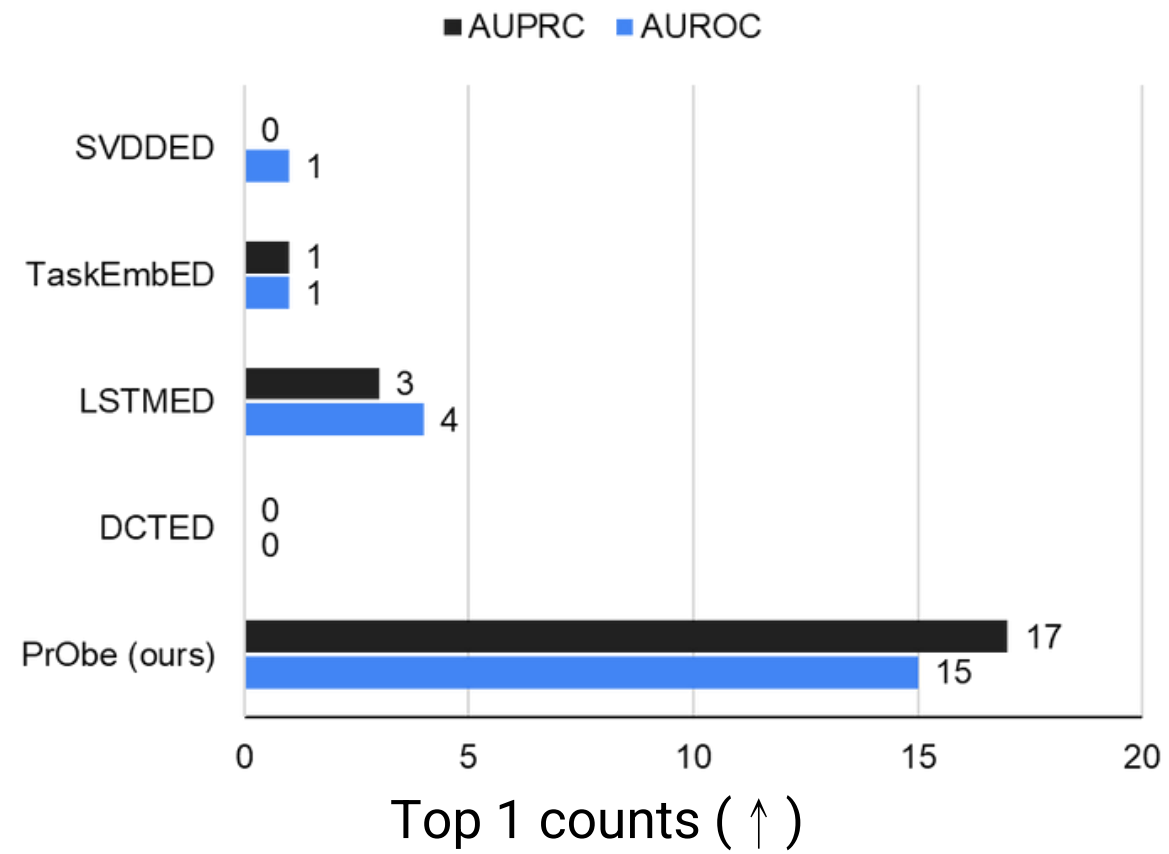


indoor scenes

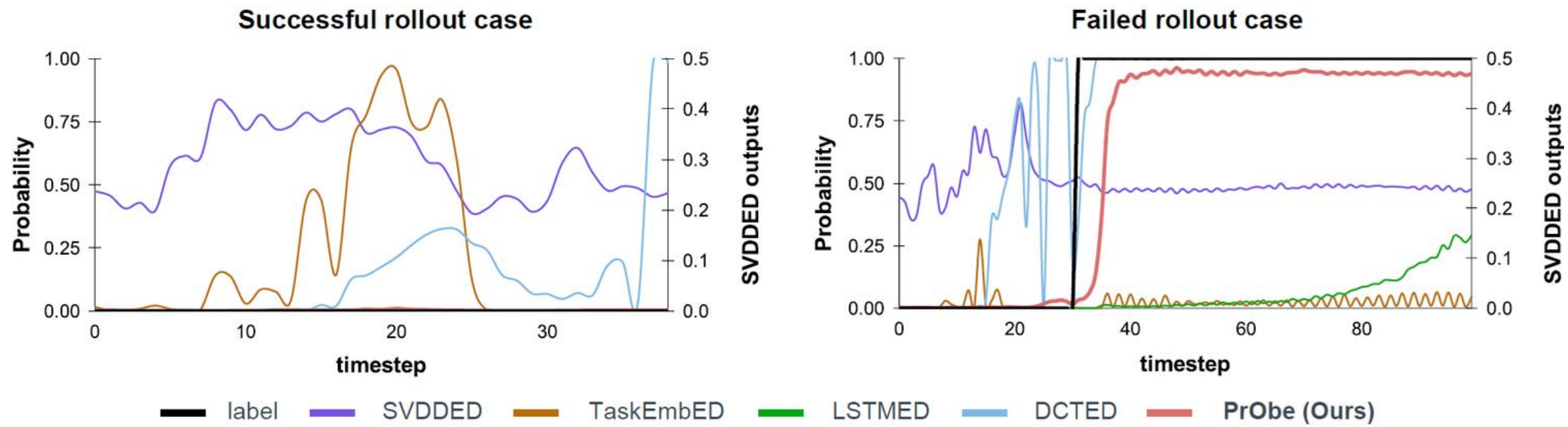
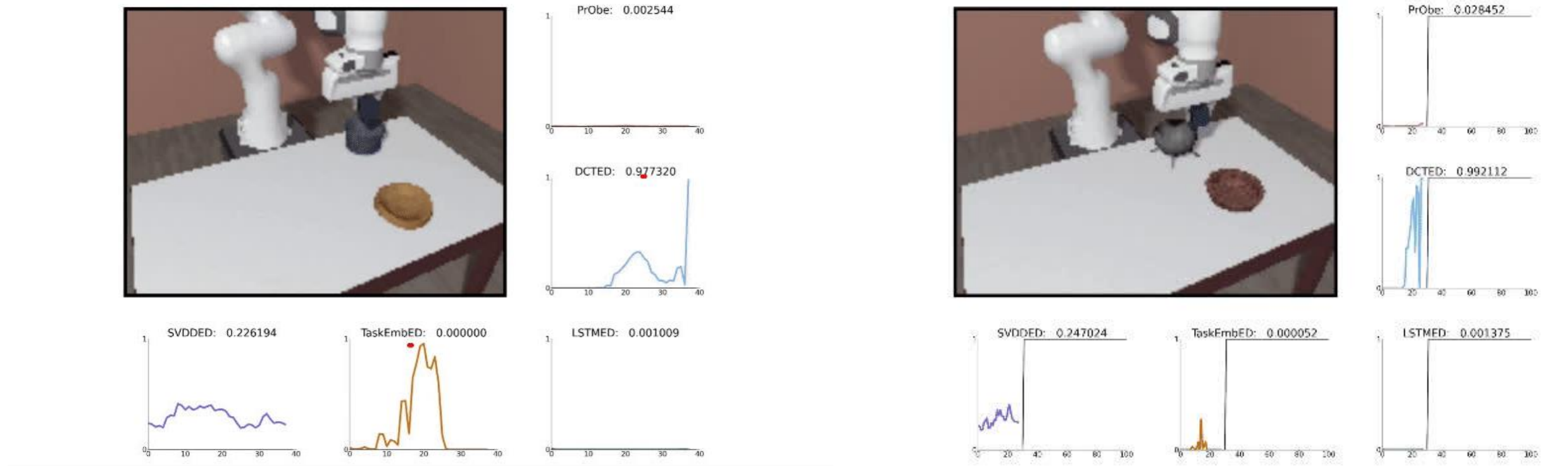


industrial scene

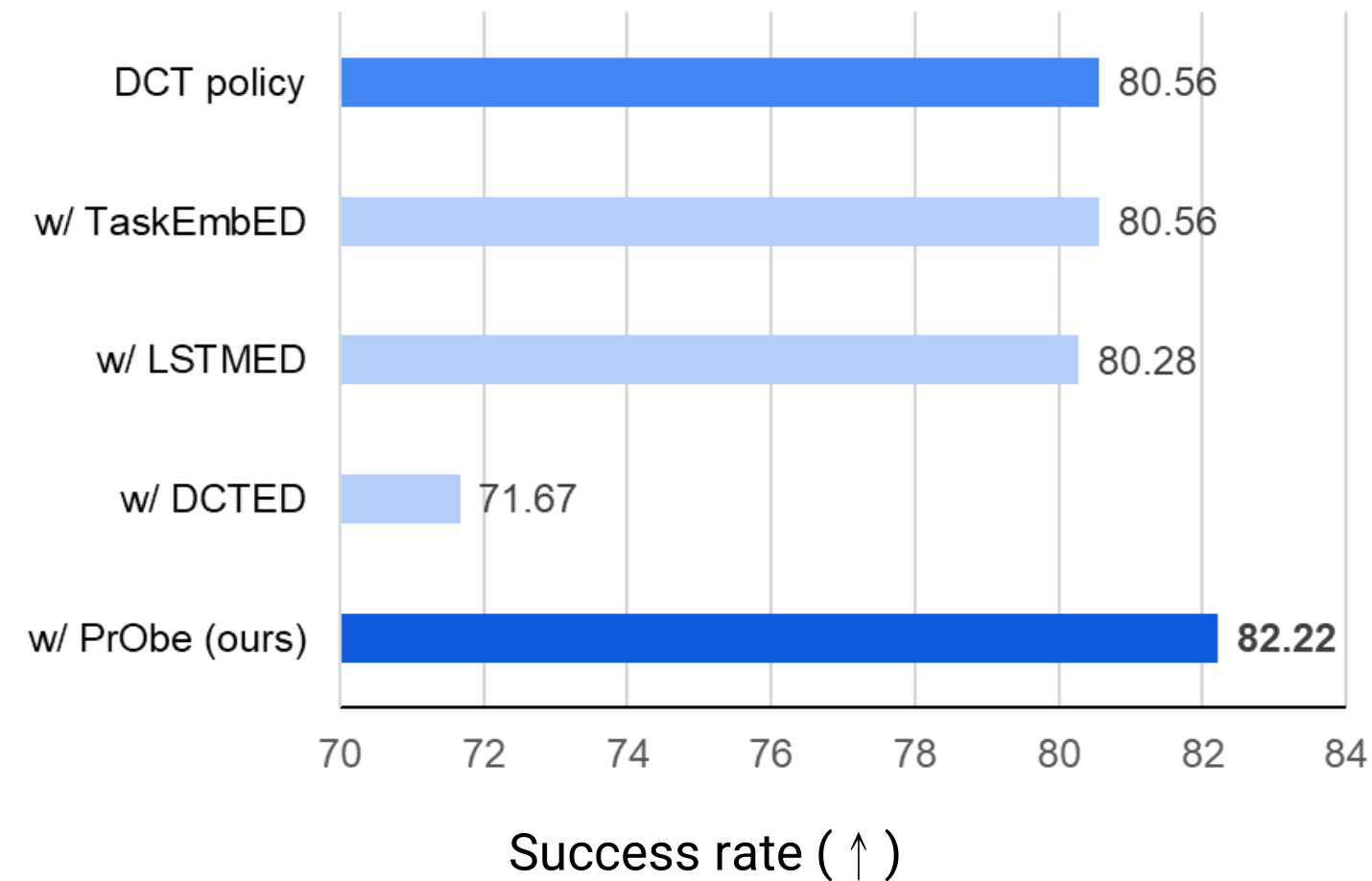
Main Results



Timing Accuracy Experiments



Pilot Study on Error Correction



- Conducted on the *Press Button* task
- The correction policy will move the robotic arm to a safe pose
- Only the case collaborated with our PrObe achieves better results

Summary & Takeaway

- We introduce AED, a new task for detecting erroneous behaviors in FSI policies
- We develop an associated AED benchmark to provide a unified evaluation platform
- We propose PrObe, an AED method that detects erroneous behaviors by extracting patterns in the policy's features
- Our PrObe effectively addresses the AED task and outperforms the compared baselines across various tasks and policies

