Artificial Intelligence (AI) for Dynamical and Safety-critical Systems

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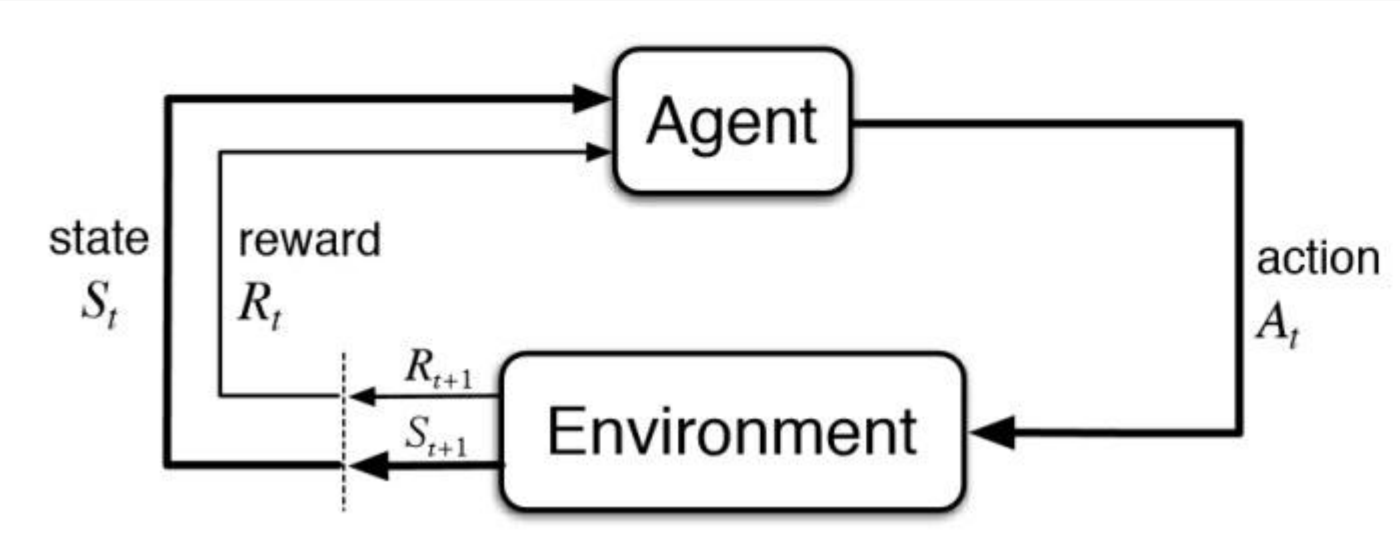
Artificial Intelligence

1. Supervised Learning
   a. Learn by using labelled data
   b. Regression, Classification
2. Reinforcement Learning
   a. Work on interacting with the environment
   b. Decision-making
3. Unsupervised Learning
   a. Train by using unlabelled data w/o any guidance
   b. Clustering

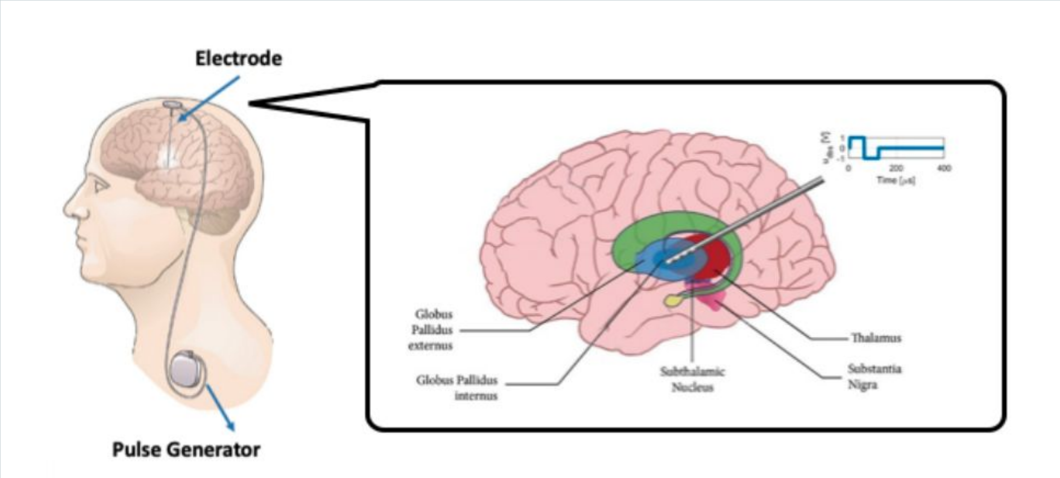
Standard Reinforcement Learning (RL)



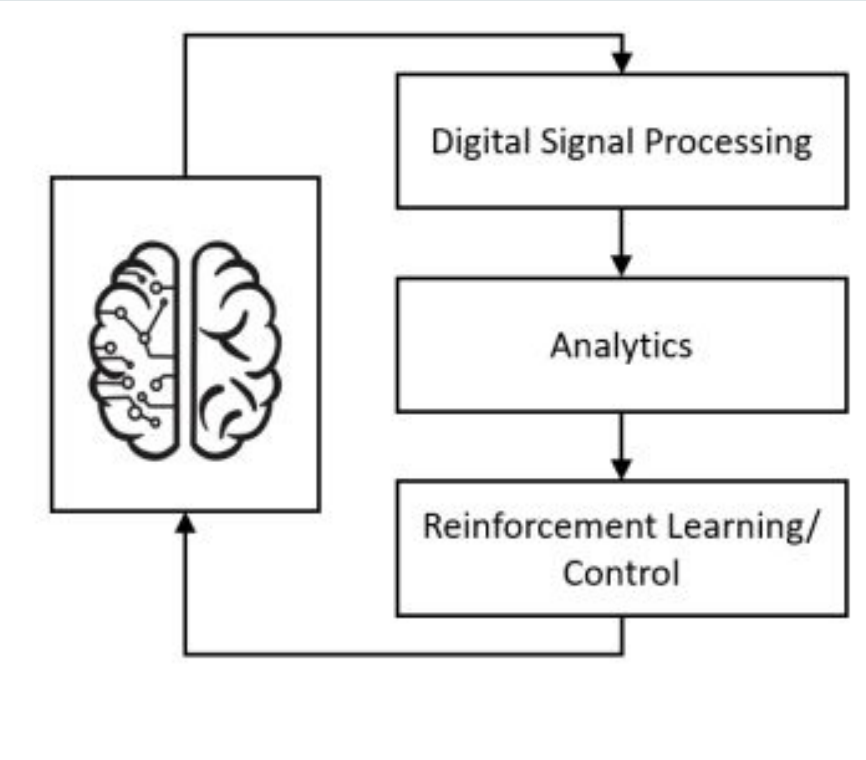
1. Dynamical & Safety-critical Systems

Deep brain stimulation (DBS) is an effective procedure to treat motor symptoms caused by nervous system disorders such as Parkinson's disease (PD)

- Commercial DBS: fixed parameters (e.g., pulse frequency and amplitude)
    - Do not consider the dynamics of the neural populations
    - Constant large parameters shorten battery life and result in side effects to patients
    - Tuning is time-consuming and requires expertise
- Closed-loop aDBS:
    - Reduce energy consumption and side effects
    - Still requires substantial efforts to configure the parameters



Computational Model in Open Gym Environment



- Pure RL-based DBS:
  - Goal: synchrony suppression under electrical stimulation
  - Non-fixed parameters can achieve better stimulation efficacy and energy efficiency
  - Data-driven approach for configuring parameters

Bonhoeffer–van der Pol model :

$$\left\{ \begin{array}{l} \dot{x} = x_k - \frac{x_k^3}{3} - y_k + I_k + \epsilon X + A \\ \dot{y} = 0.1(x_k - 0.8 y_k + 0.7), \end{array} \right\}$$

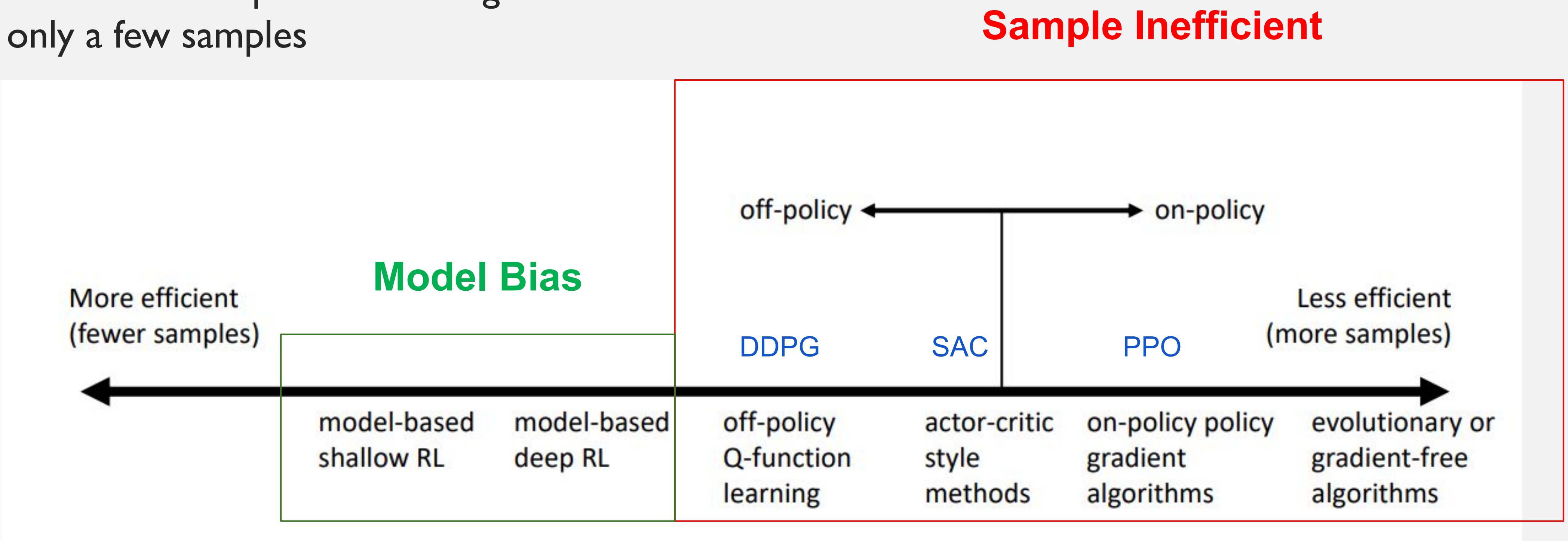
Reward in RL :

$$R(t) = exp^{(-(X(t) - <X_{state}>)^2 - \beta |A_t|)}.$$

Category of RL from Sample Efficiency Perspective

Model bias: assume that learned dynamics model sufficiently resembles real environment

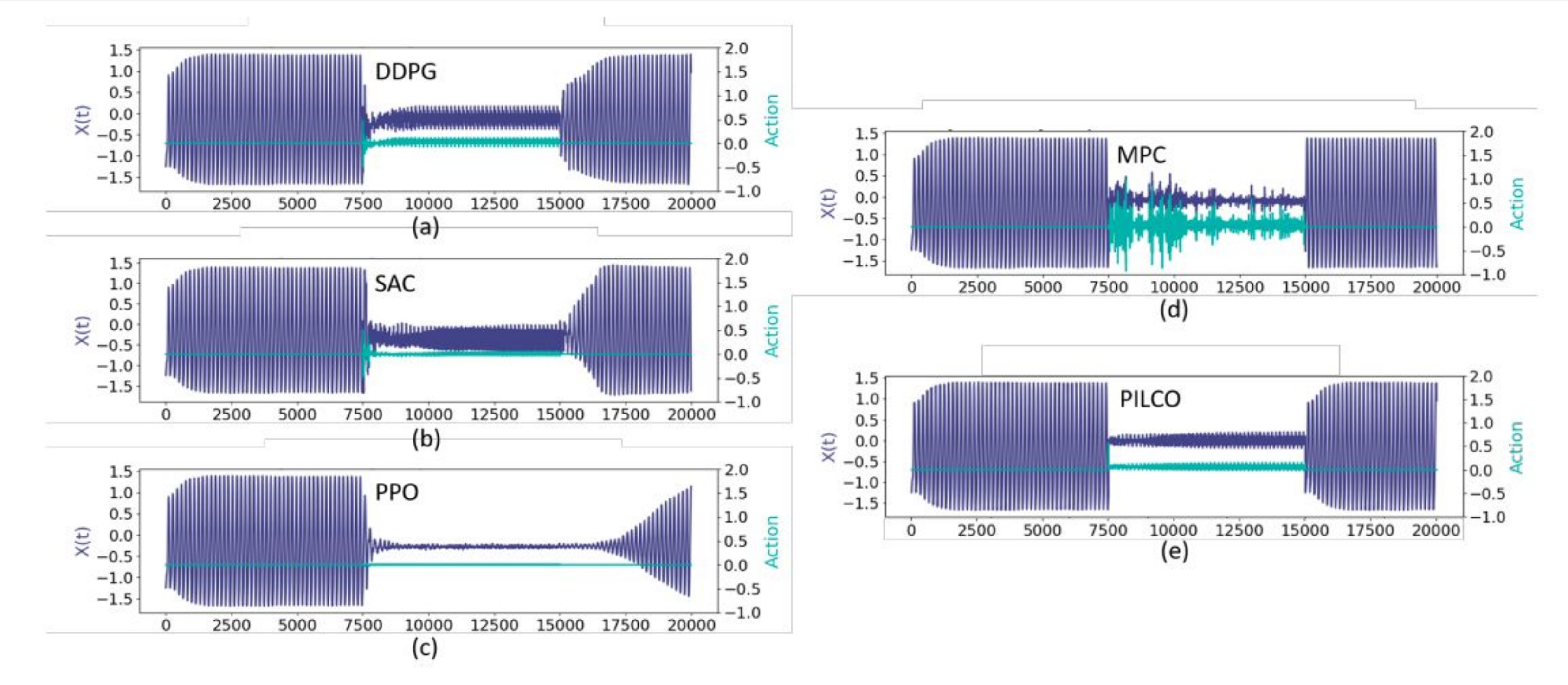
- no informative prior knowledge about the task
- only a few samples



Probabilistic Inference for Learning Control (PILCO)

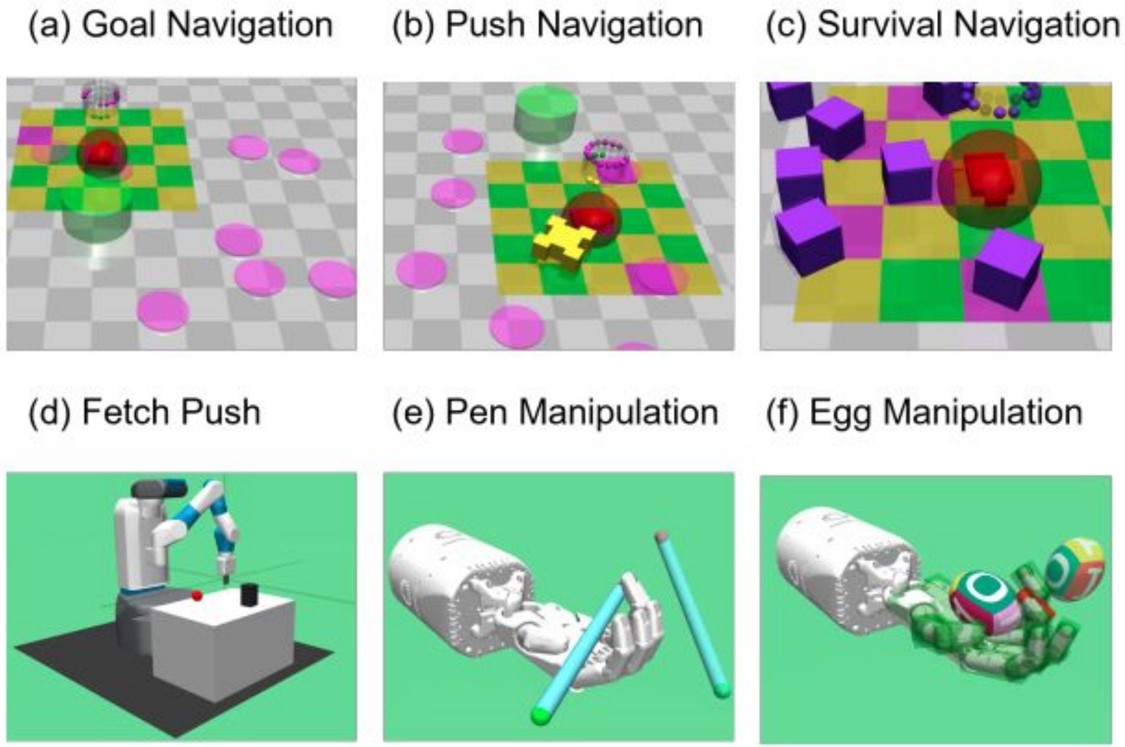
1. Model-based
2. Employ Gaussian Process to incorporate model uncertainty
   a. reduce model bias
   b. facilitate learning from scratch in a few trials with good performance in evaluation

Results in Synchrony Suppression Task

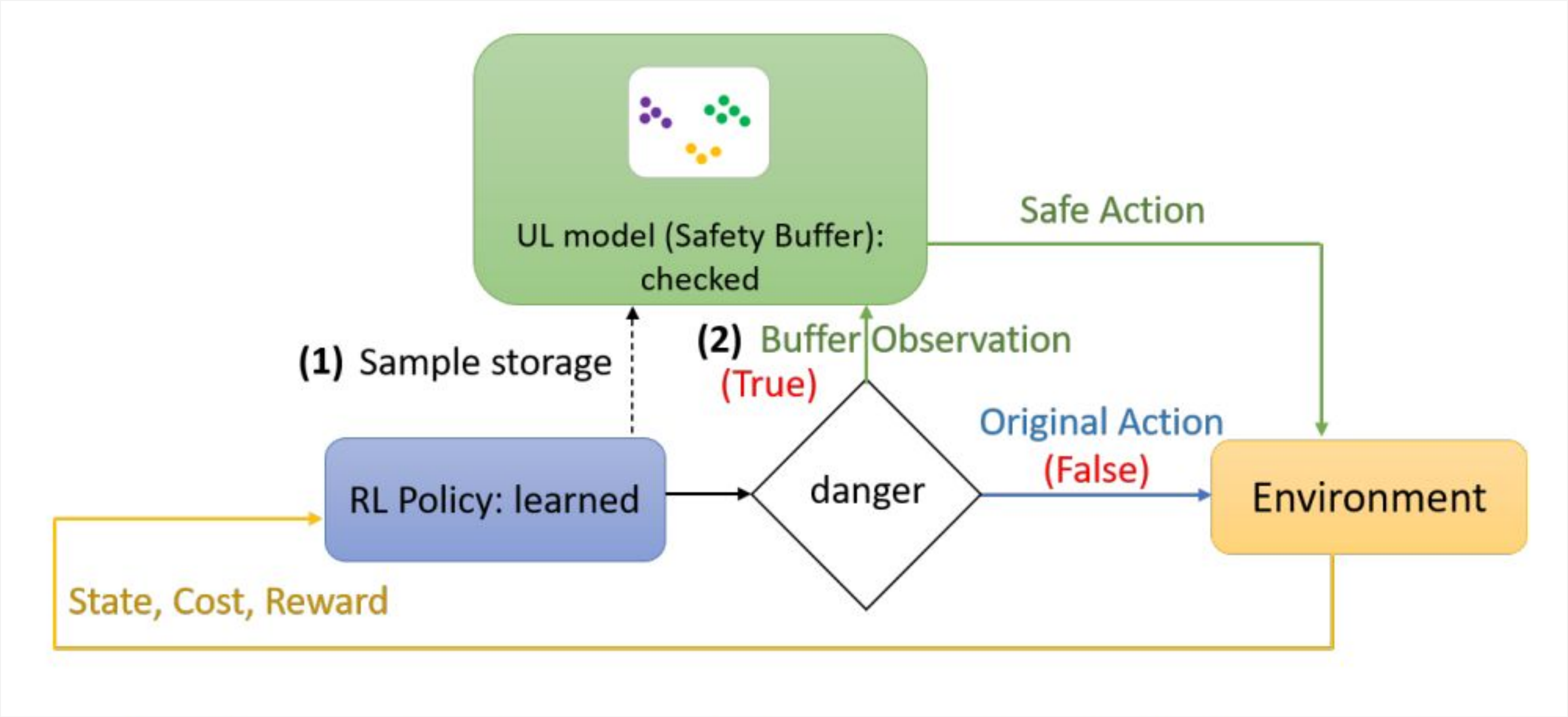


2. Dynamical & Safety-critical Systems

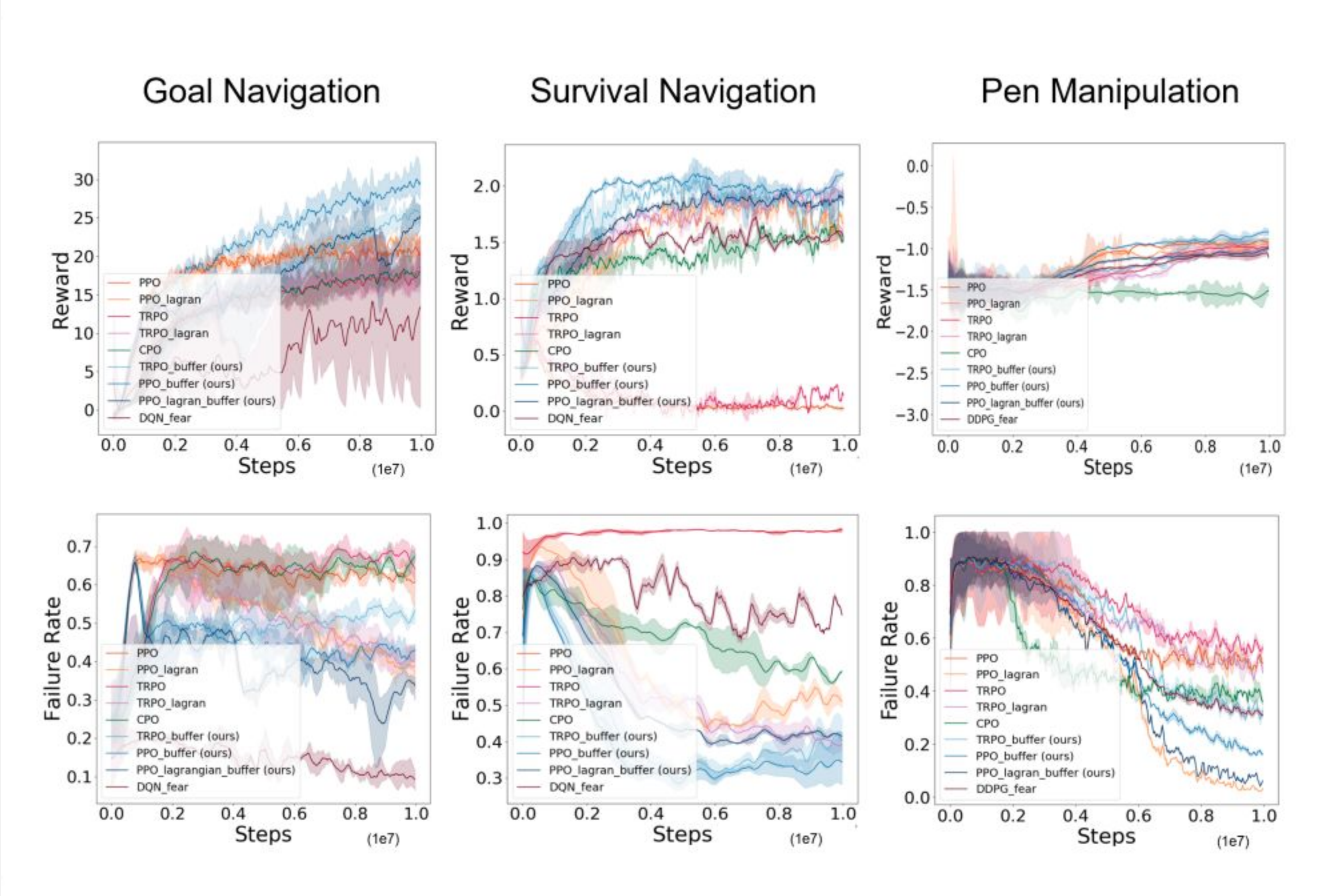
Six robotic control tasks, including navigation and manipulation



Augment RL with Unsupervised Learning Model



Results in Robotic Control Tasks



Thanks for Listening