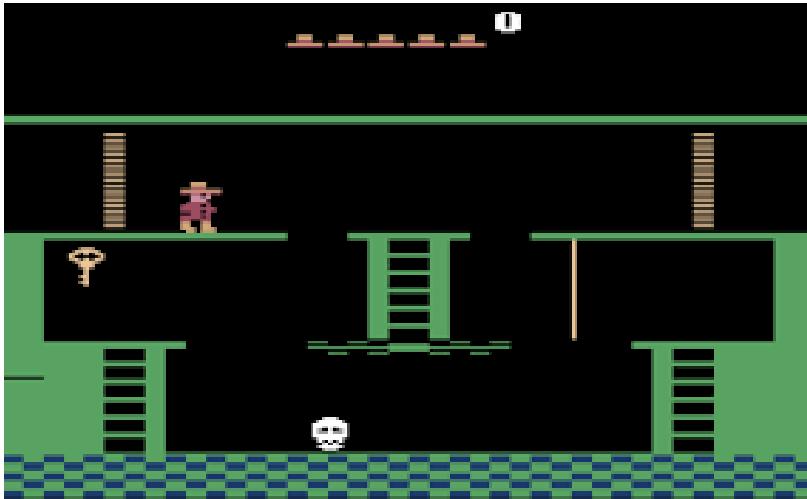


Transfer and Meta Learning

- Last time:
 - Imitation Learning
 - Inverse Reinforcement Learning
- Today:
 - How do we **transfer** knowledge from one domain to another?
(e.g. simulated to real-world)
 - How do we learn how to learn? (**Meta** learning)

Transfer Learning and Montezuma's Revenge



Could an RL agent be better at Montezuma's revenge after watching Indiana Jones?

Transfer Learning

Transfer Learning: Use experience from one set of tasks for faster learning and better performance on a new task

In RL, task=MDP

Source domain → target domain

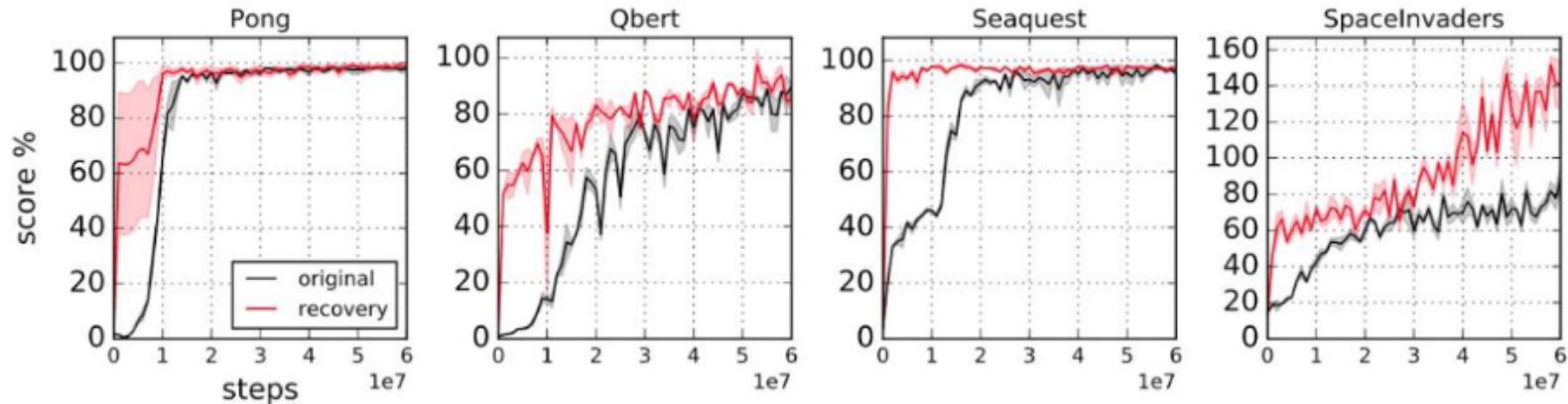
- "shot" = number of attempts in the target domain
- "0-shot" = run policy in target domain
- "1-shot" = try task once
- "few shot"

Transfer Learning

How should prior knowledge be stored?

- Q-function
- Policy
- Model
- Features/hidden states

Representation Bottleneck

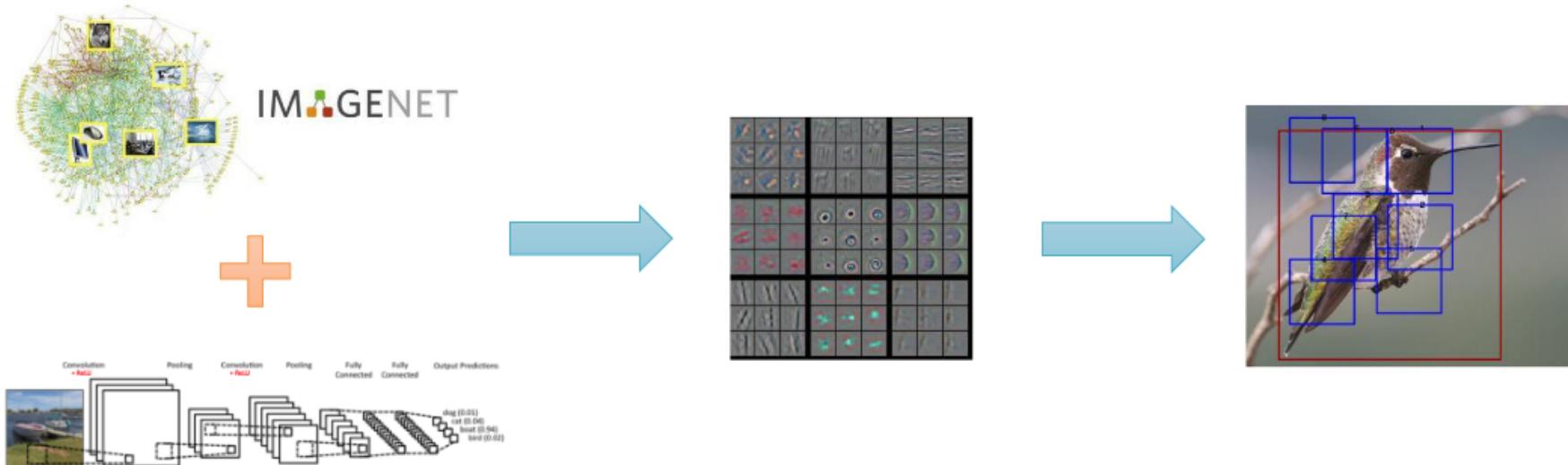


Transfer Learning

How should prior knowledge be stored?

- Q-function
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- Model
- Features/hidden states

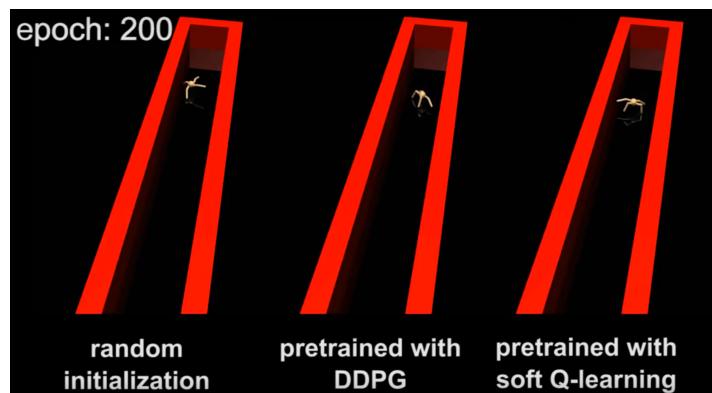
Pretraining + Finetuning



Pretraining + Finetuning



Pretrain: reward speed in any direction

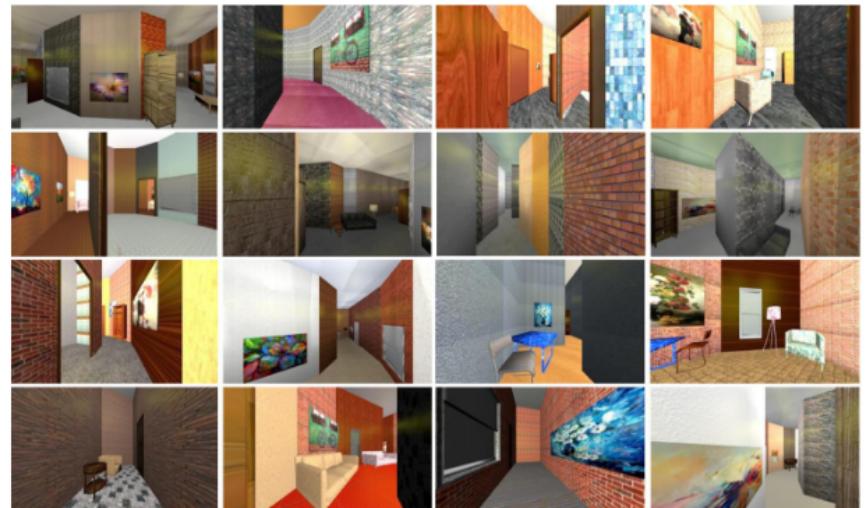


Fine Tune: reward speed in specific direction

$$\pi(a|s) \propto_a \exp(Q(s, a))$$

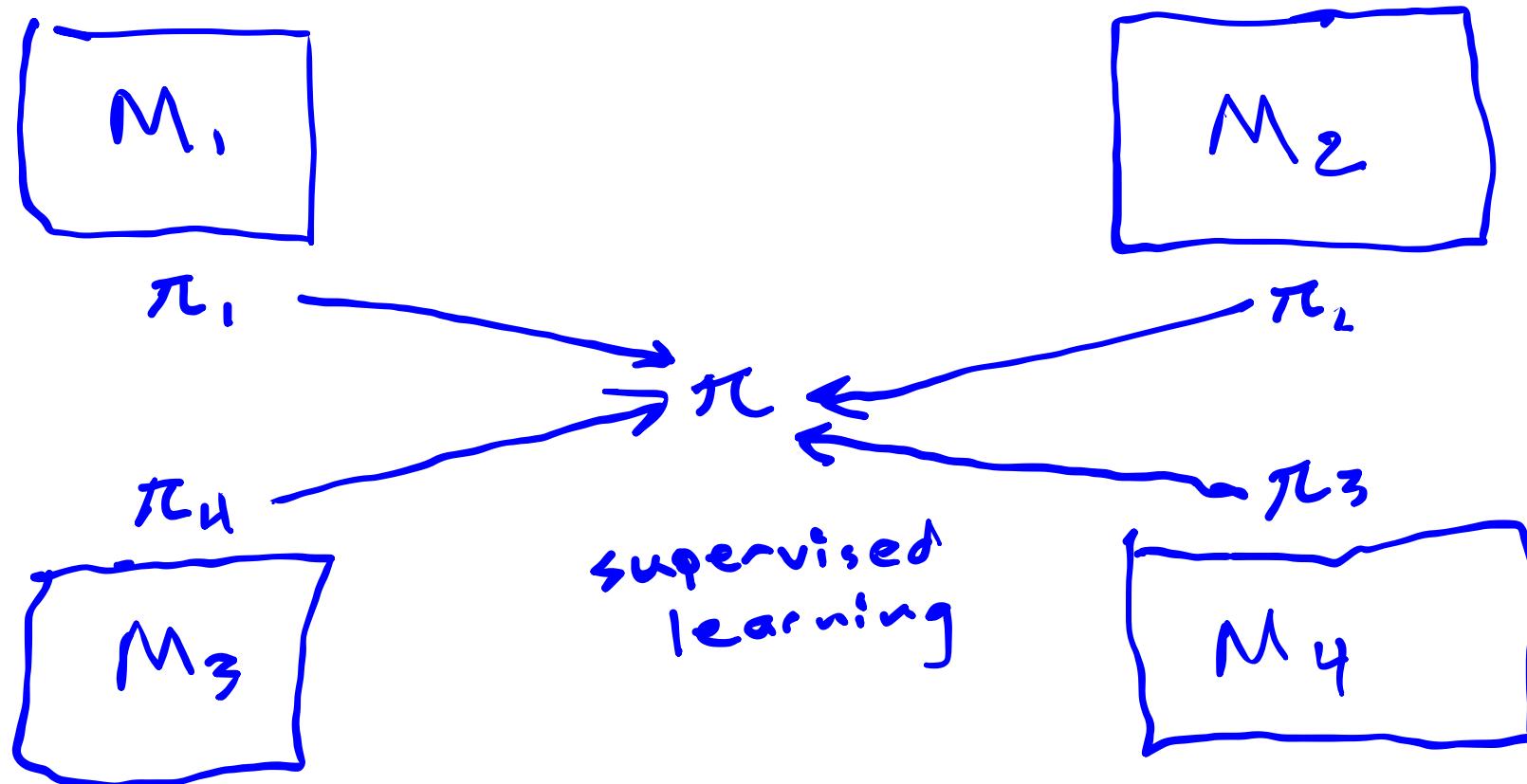
<https://sites.google.com/view/softqlearning/home>

CAD2RL



Key: Diversity

Actor Mimic



Transfer Learning

How should prior knowledge be stored?

- Q-function
- Policy
- Model
- Features/hidden states

Successor Features

All domains have same S, A, T, γ

Difference: R

Let $R(s, a) = w^\top \phi(s, a)$ where ϕ is a feature vector.

$$\begin{aligned} Q^\pi(s, a) &= E \left[\sum_{t=0}^{\infty} \gamma^t R(s, a) \mid s_0 = s, a_0 = a \right] \\ &= E \left[\sum_{t=0}^{\infty} \gamma^t w^\top \phi(s, a) \mid s_0 = s, a_0 = a \right] \\ &= w^\top E \left[\sum_{t=0}^{\infty} \gamma^t \phi(s, a) \mid s_0 = s, a_0 = a \right] \end{aligned}$$

Successor Feature:

$$\begin{aligned} \psi^\pi(s, a) &\equiv E \left[\sum_{t=0}^{\infty} \gamma^t \phi(s, a) \mid s_0 = s, a_0 = a \right] \\ Q^\pi(s, a) &= w^\top \psi^\pi(s, a) \end{aligned}$$

Using successor features

$$\psi^\pi(s, a) \equiv E \left[\sum_{t=0}^{\infty} \gamma^t \phi(s, a) \mid s_0 = s, a_0 = a \right] \quad Q^\pi(s, a) = w^\top \psi^\pi(s, a)$$

Given ψ^π , one can easily calculate Q'^π for a new reward function $R' = w'^\top \phi$.

$$Q'^\pi = w'^\top \psi^\pi$$

Important: Does this yield optimal policy for R' ?

No!

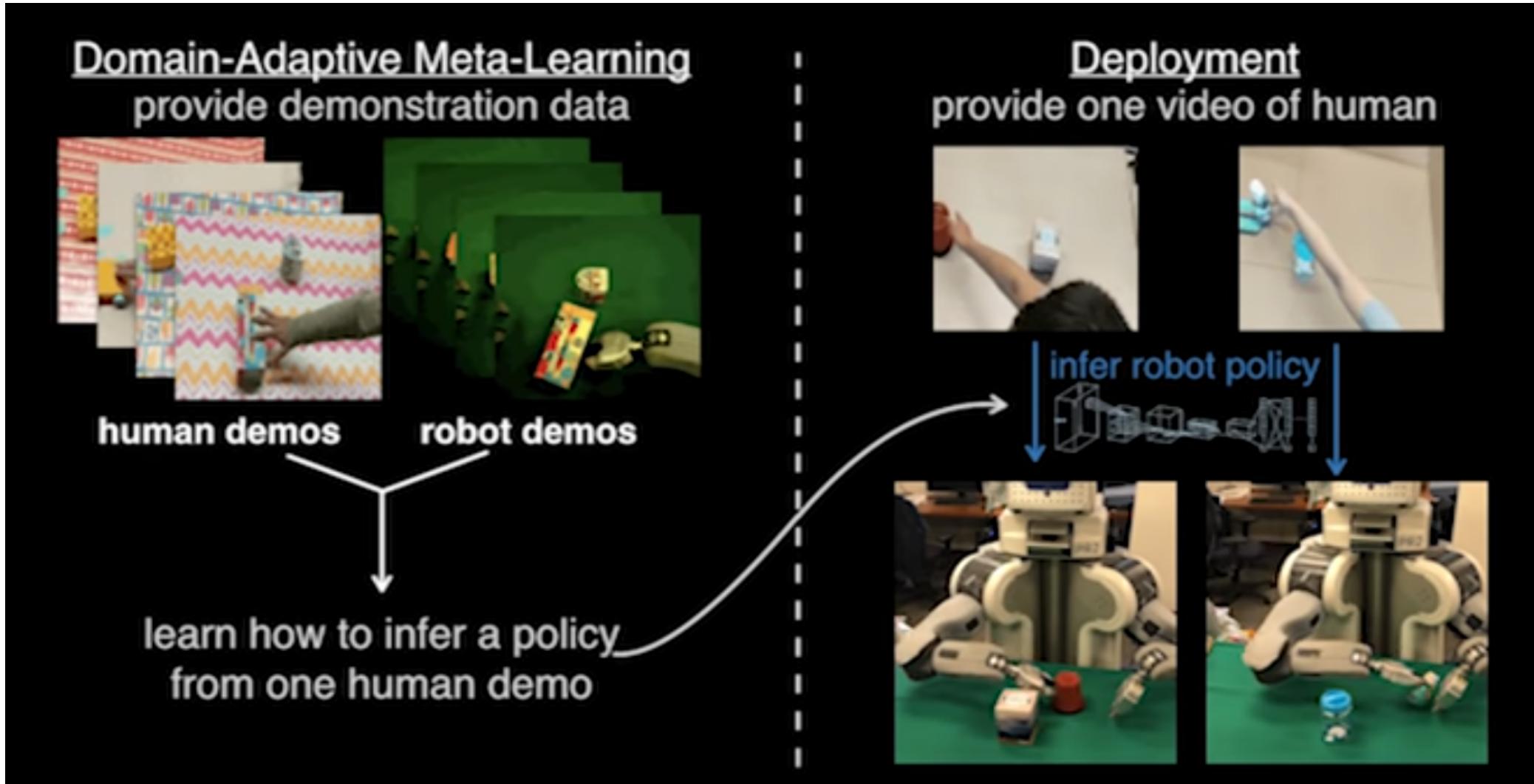
$$Q^\pi(s, a) = R(s, a) + \gamma E[Q^\pi(s', \pi(s'))]$$

$$Q^*(s, a) = R(s, a) + \gamma \max_{a'} E[Q^*(s', a')]$$

How to use this in practice:

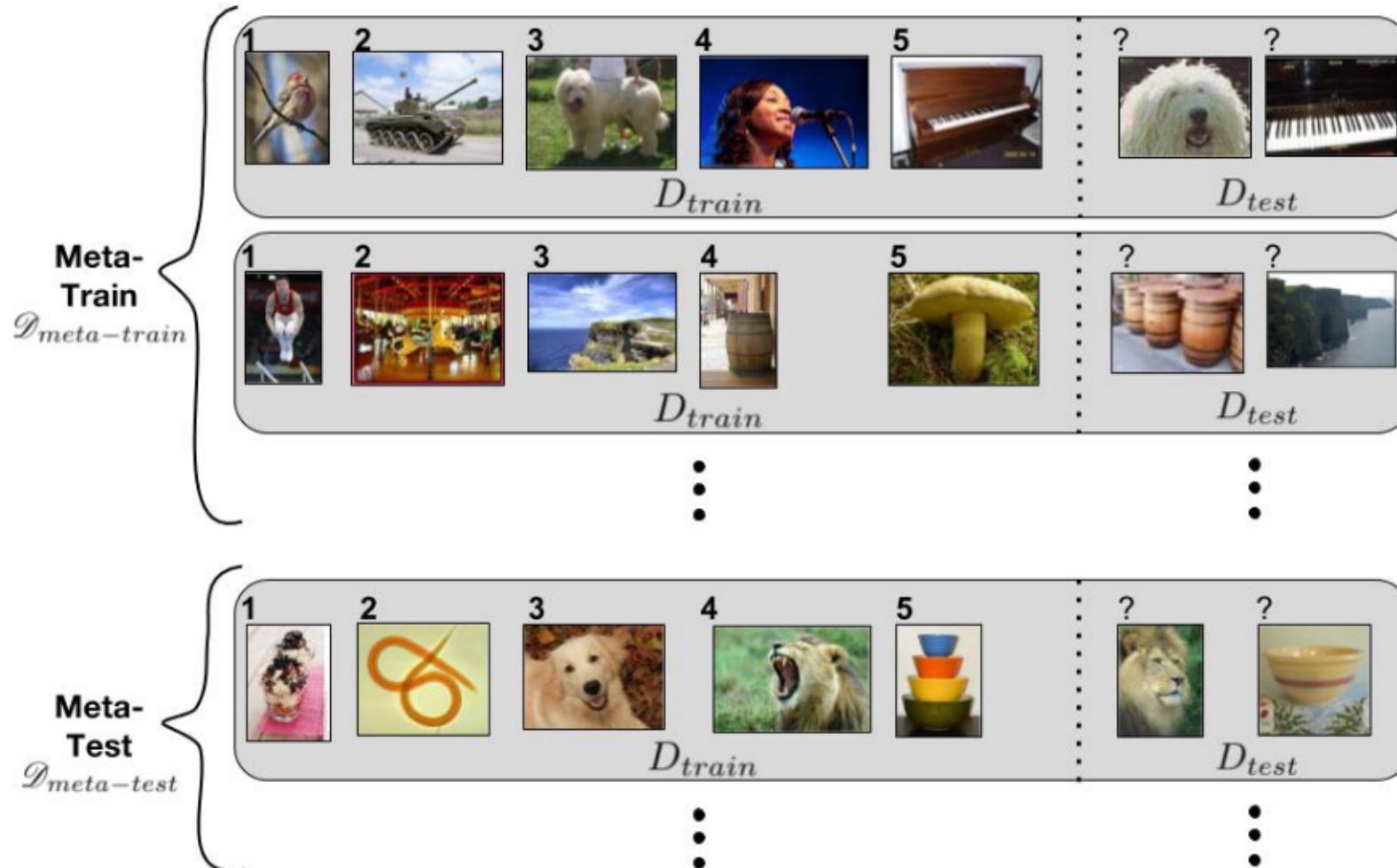
- Keep a family of good policies and associated successor features with a variety of weights.
- In target domain, start with best policy from this set and finetune/plan online

Meta Learning: Motivation



https://www.youtube.com/watch?v=1eYqV_vGIJY

Meta Learning



Meta Reinforcement Learning

RL

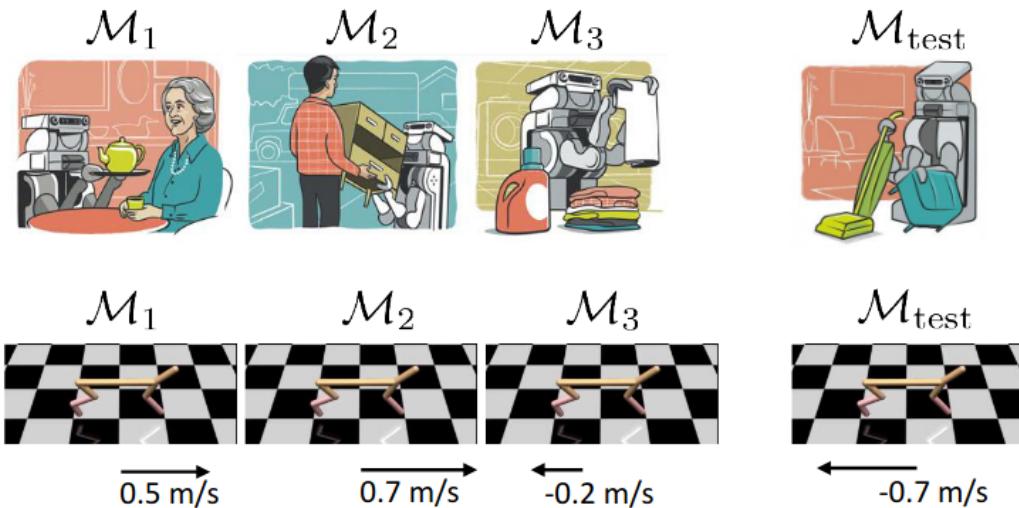
$$\theta^* = \operatorname{argmax}_{\theta} \mathbb{E}_{\pi_{\theta}} [R(\tau)]$$

$$= f_{\text{RL}}(M)$$

Meta RL

$$\theta^* = \operatorname{argmax}_{\theta} \sum_{i=1}^n \mathbb{E}_{\pi_{\phi_i}} [R(\tau)]$$

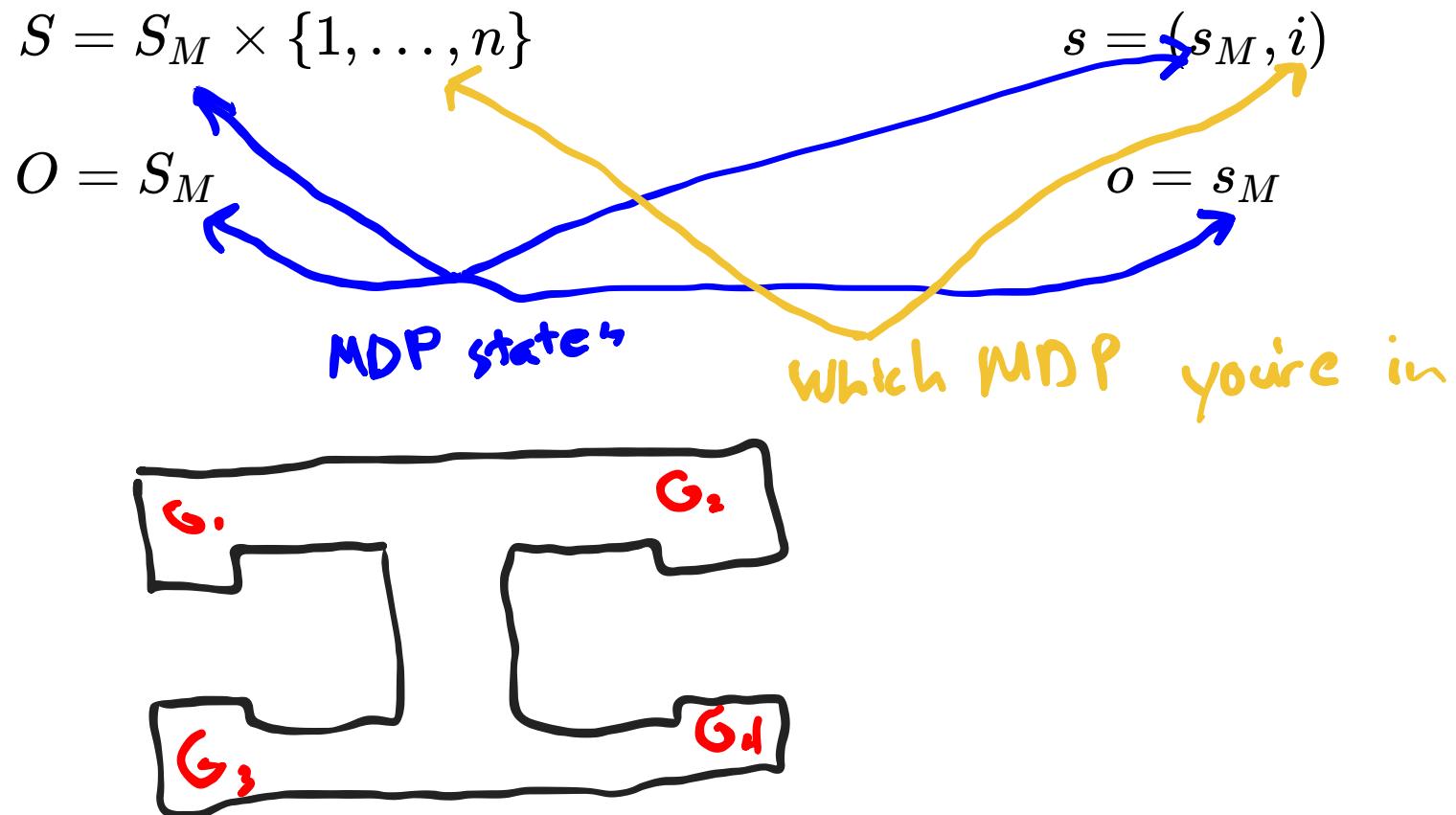
$$\text{where } \phi_i = f_{\theta}(M_i)$$



Important: Exploration can
speed up Meta RL

Meta Reinforcement Learning

Approach 1: Pose as POMDP



Meta Reinforcement Learning

Approach 2: Gradient-Based Meta-RL (MAML)

RL: Policy Gradient

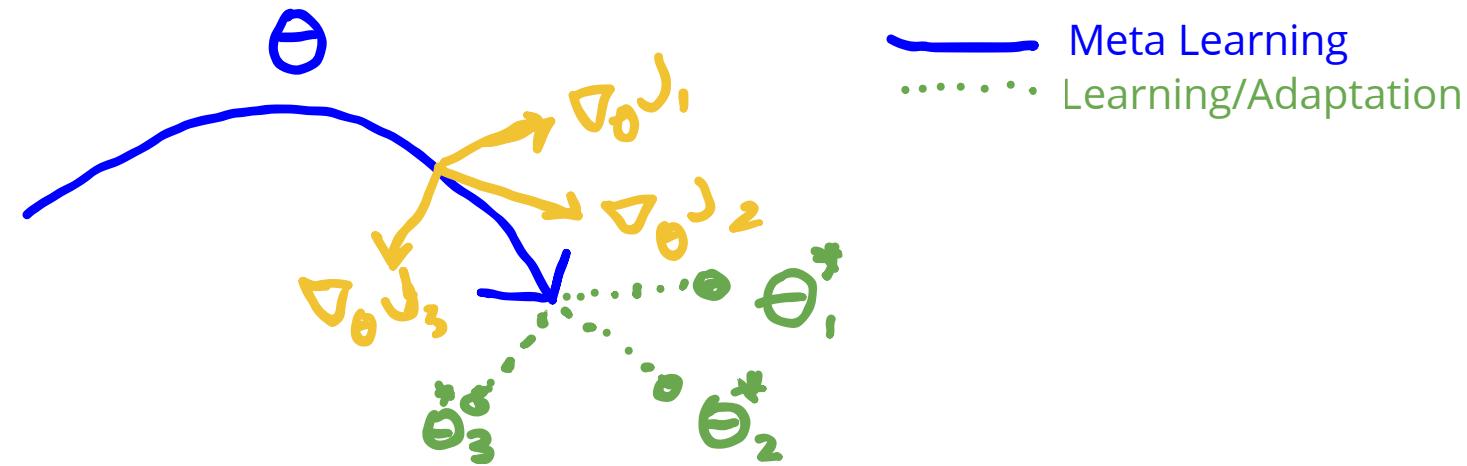
$$\theta^{k+1} \leftarrow \theta^k + \alpha \nabla_{\theta} J(\theta^k)$$

Model Agnostic Meta Learning (MAML) for RL

$$f_{\theta}(M_i) = \theta + \alpha \nabla_{\theta} J_i(\theta)$$

Meta Policy Gradient

$$\theta \leftarrow \theta + \beta \sum_i \nabla_{\theta} J_i[\theta + \alpha \nabla_{\theta} J_i(\theta)]$$



Recap

- In **Transfer Learning**, the goal is to use training from one or more **source domains** to one or more **target domains**.
- Various methods exist to transfer via knowledge stored in the **policy, model, value function, or other features**.
- In **Meta Learning**, the goal is to learn how to master a new environment quickly.
- A meta learning problem can be posed as a **POMDP**.
- In model agnostic meta learning (**MAML**), the policy is parameterized so that **one gradient step** in the new environment will produce a good policy.