Reinforcement Learning

CMPT 729 G100

Jason Peng

Overview

- What is reinforcement learning?
- Applications
- Logistics

What is **Reinforcement Learning**?

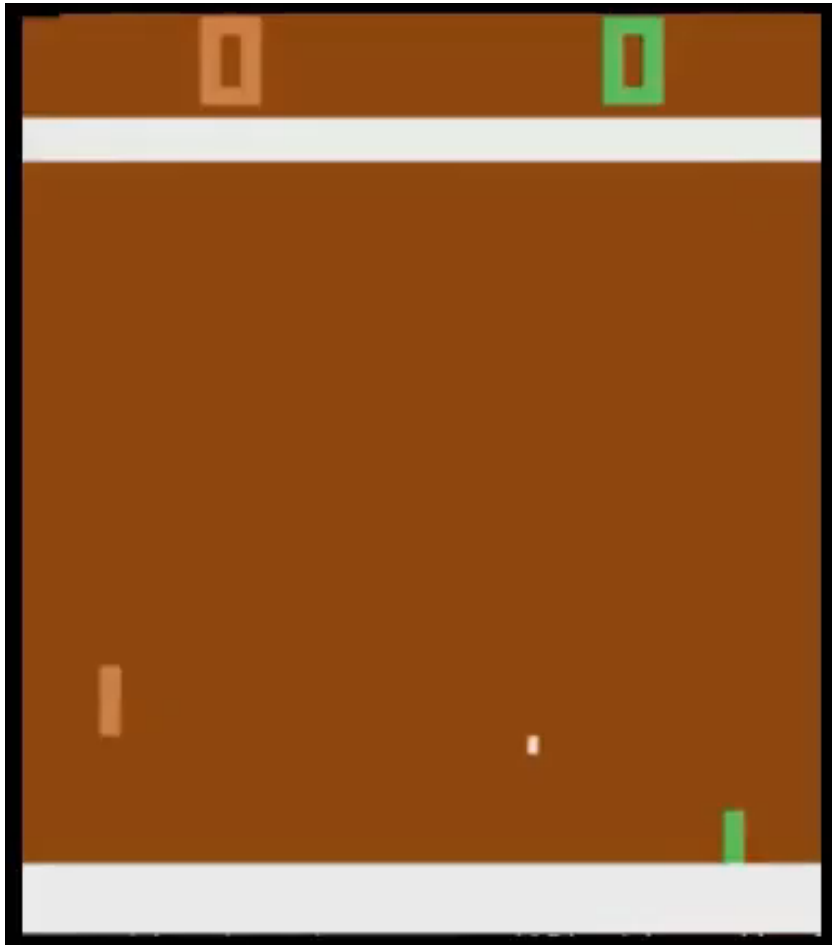
What is Reinforcement Learning

Reinforcement Learning = Area of machine learning that studies techniques for solving **decision making** problems.

Decision Making Problems

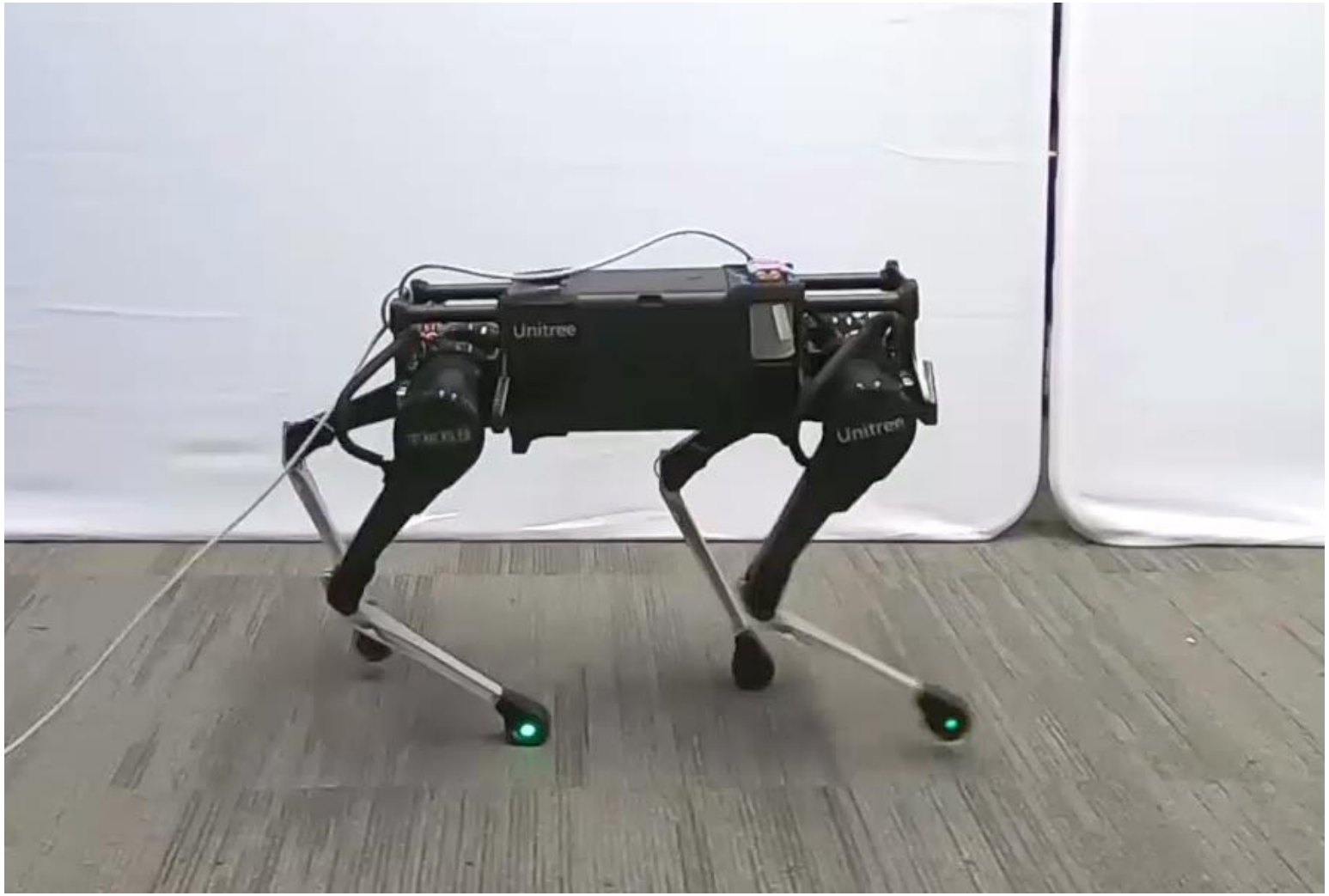
[Garry Kasparov vs. Deep Blue 1997]

Decision Making Problems

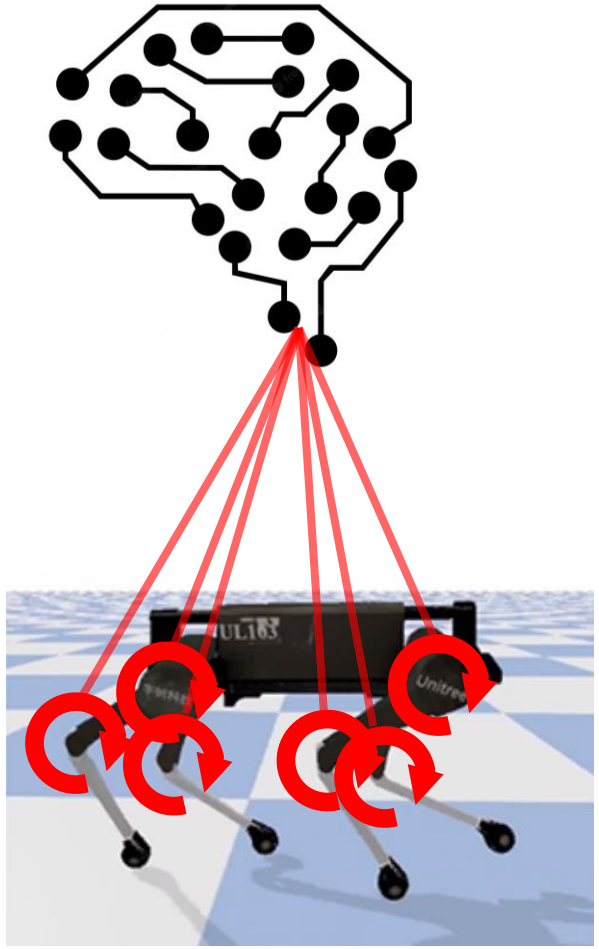


[Pong]

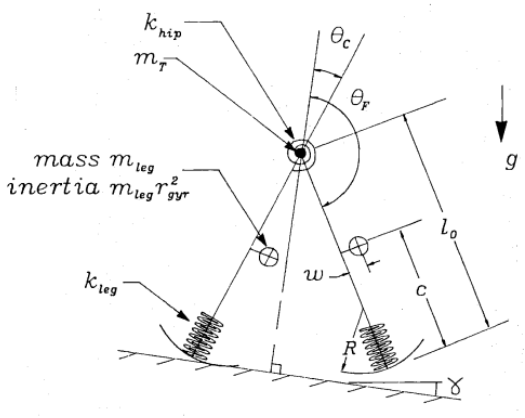
Decision Making Problems



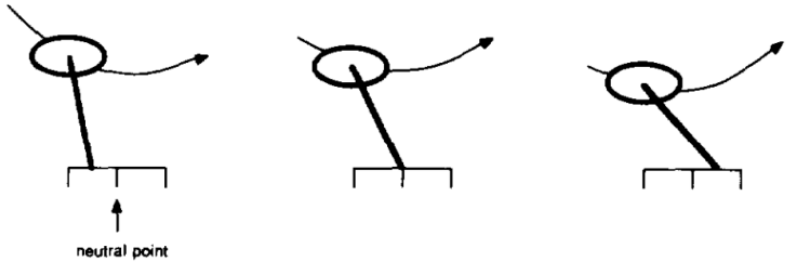
Controller



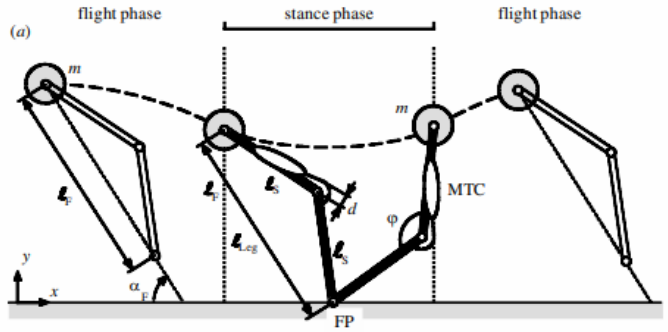
Manual Controller Design



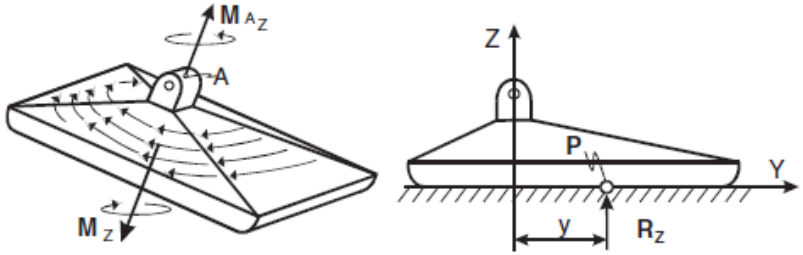
[McGeer 1990]



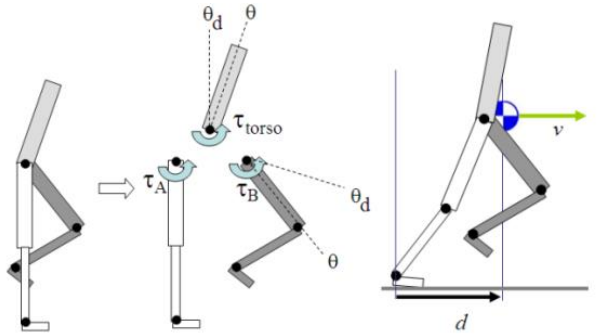
[Raibert and Hodgins 1991]



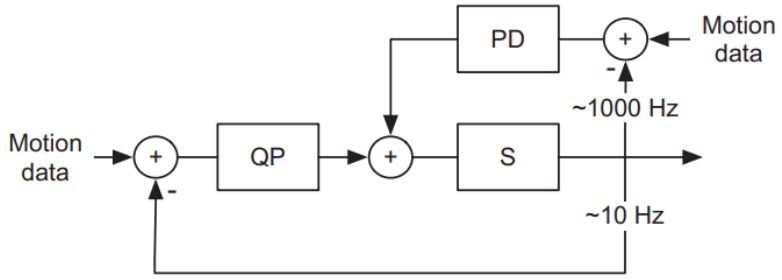
[Geyer et al. 2003]



[Vukobratović and Borovac 2004]

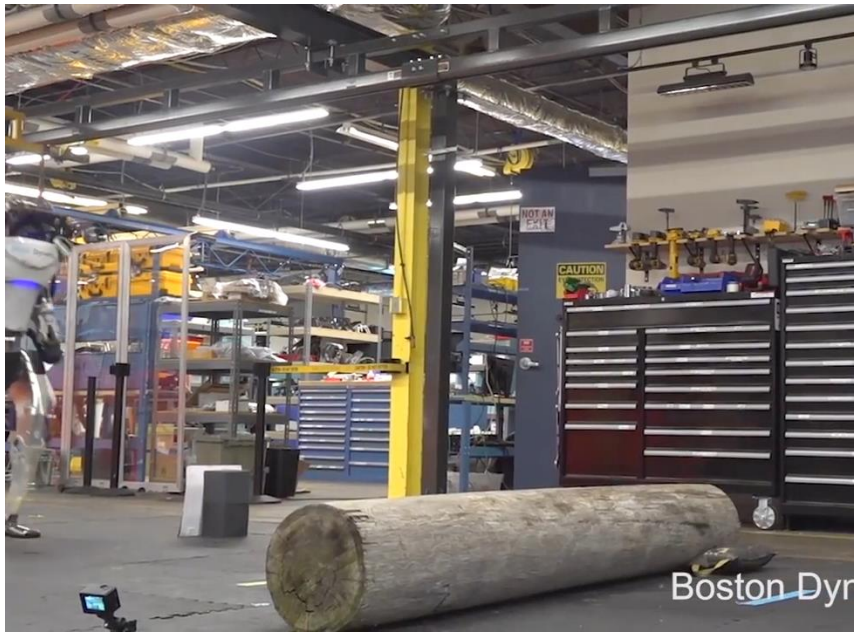


[Yin et al. 2007]



[Da Silva et al. 2008]

Manual Controller Design

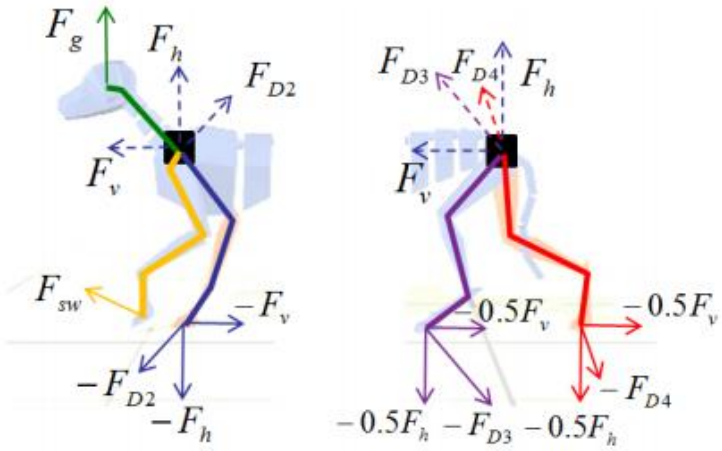


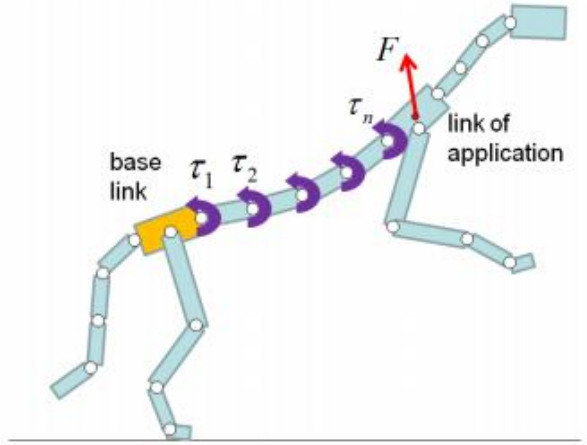
[Boston Dynamics 2018]

[ANYbotics 2018]

[MIT Biomimetic Robotics Lab 2019]

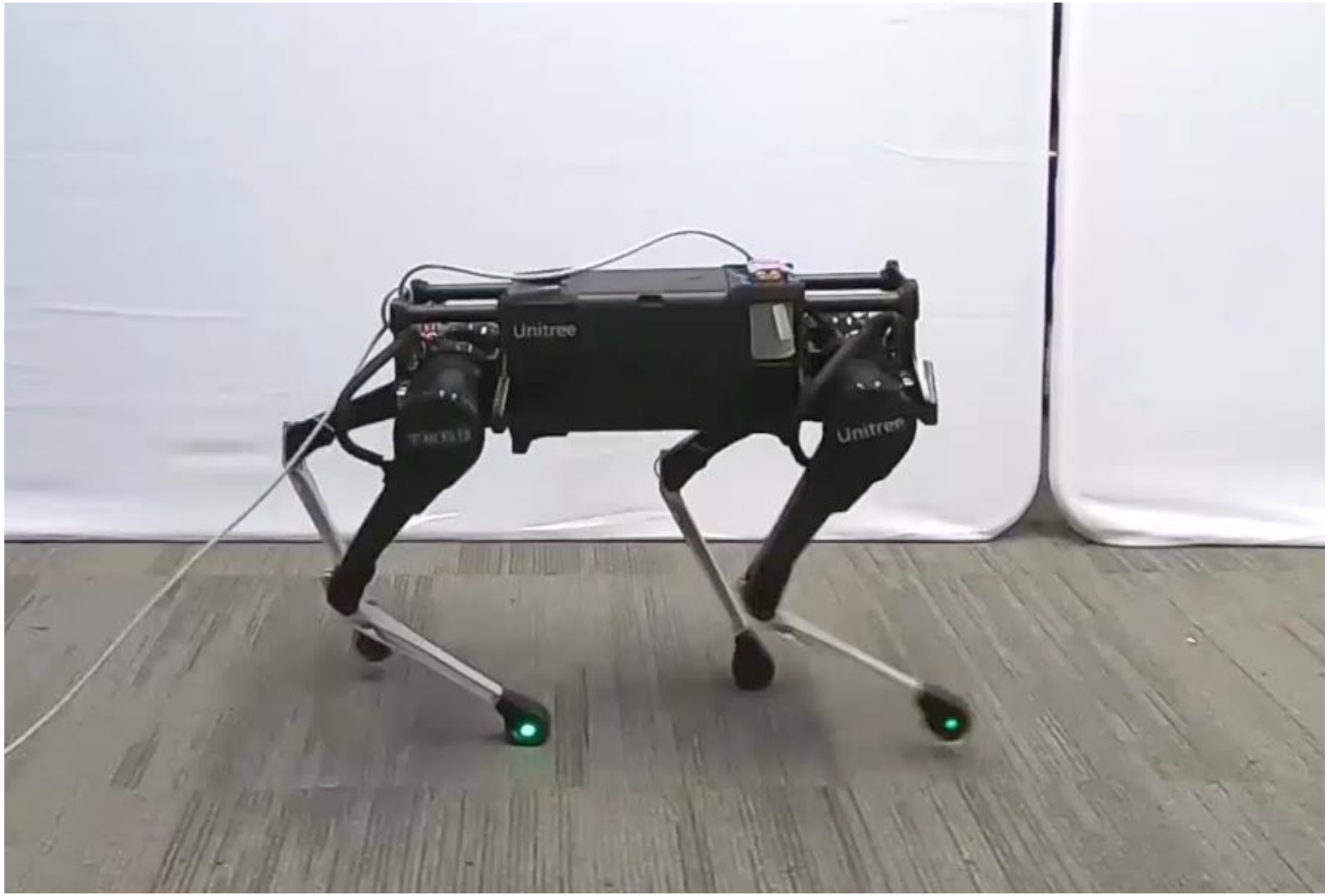
Manual Controller Design

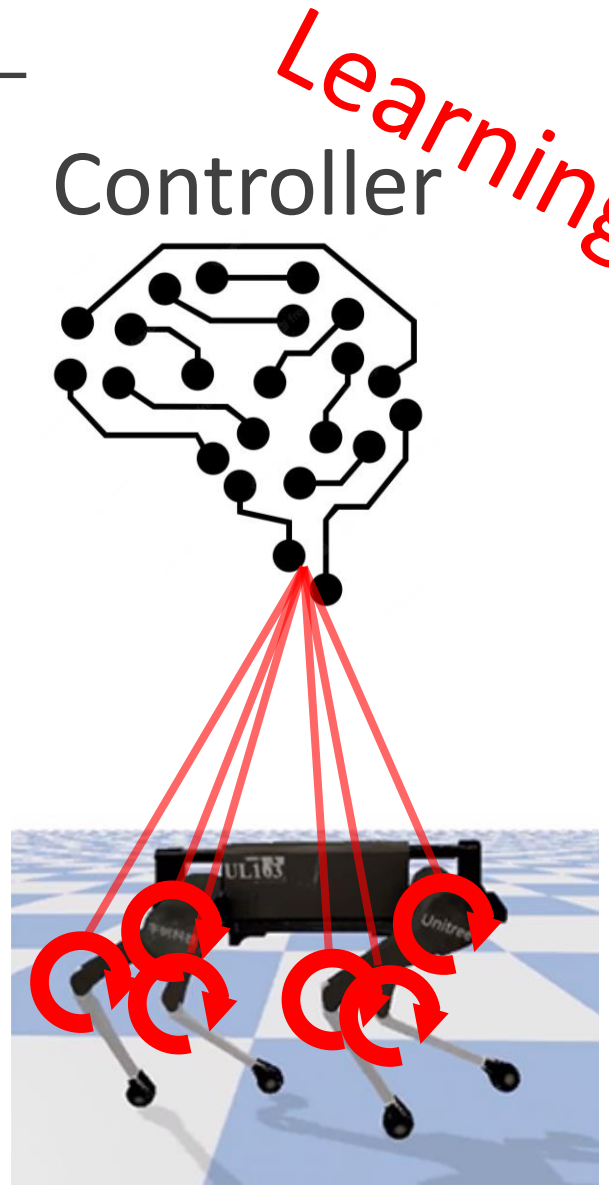




[Coros et al., 2011]

Decision Making Problems

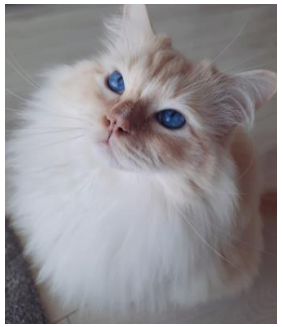


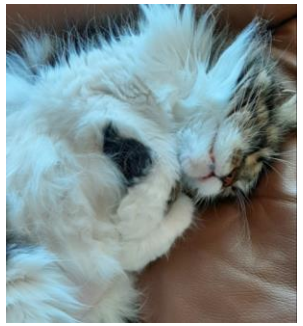


ML Paradigms

Supervised Learning

$$\{(\mathbf{x}_i, y_i)\}$$


Cat

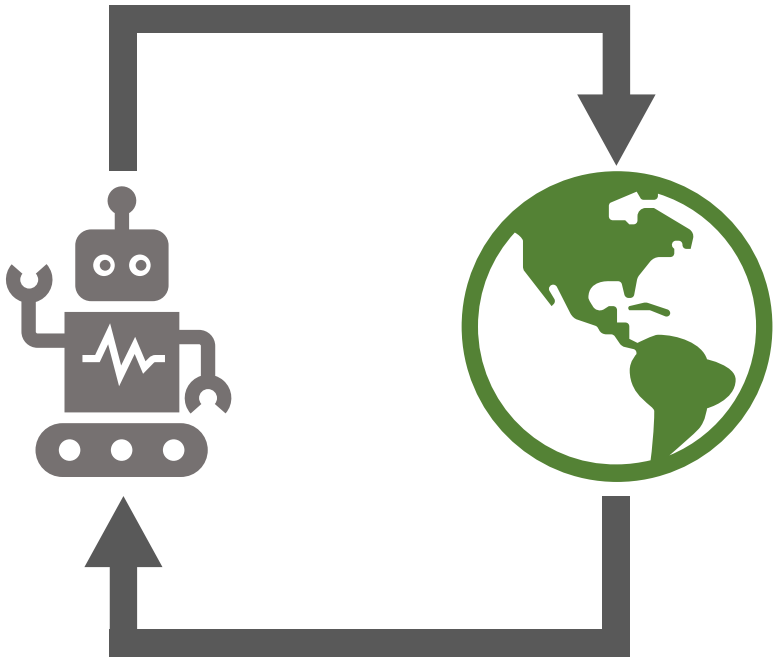

Cat


Dog


Dog

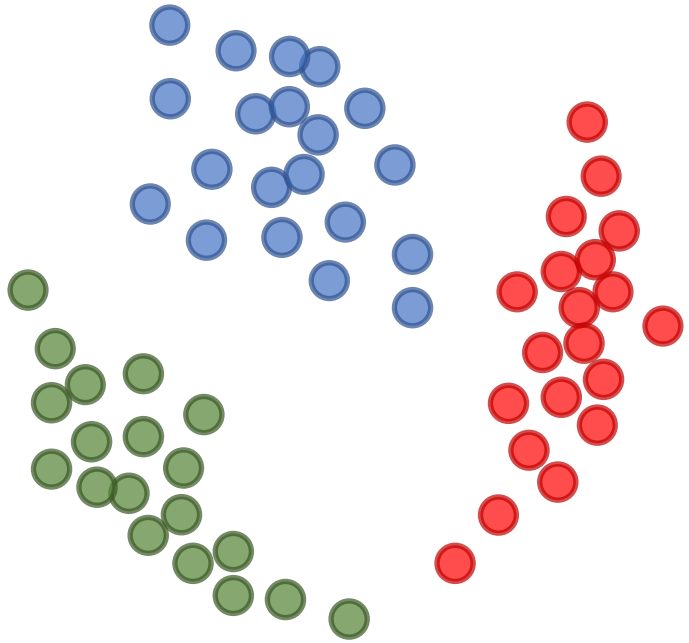
Reinforcement Learning

$$\{(\mathbf{x}_i, y_i, r_i)\}$$



Unsupervised Learning

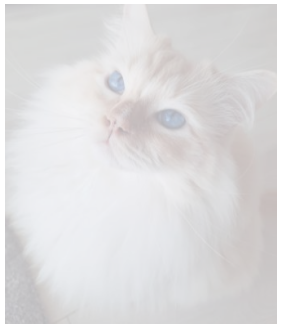
$$\{\mathbf{x}_i\}$$



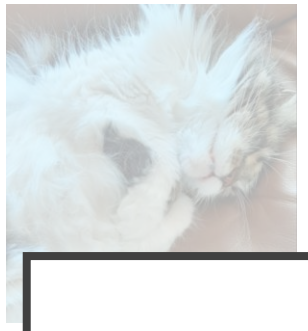
ML Paradigms

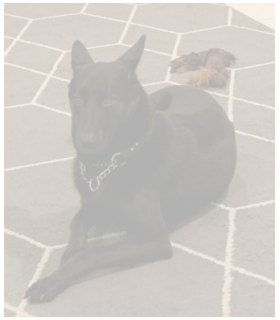
Supervised Learning

$\{(\mathbf{x}_i, y_i)\}$

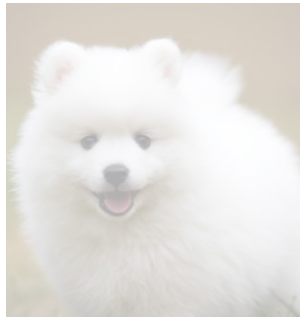


Cat





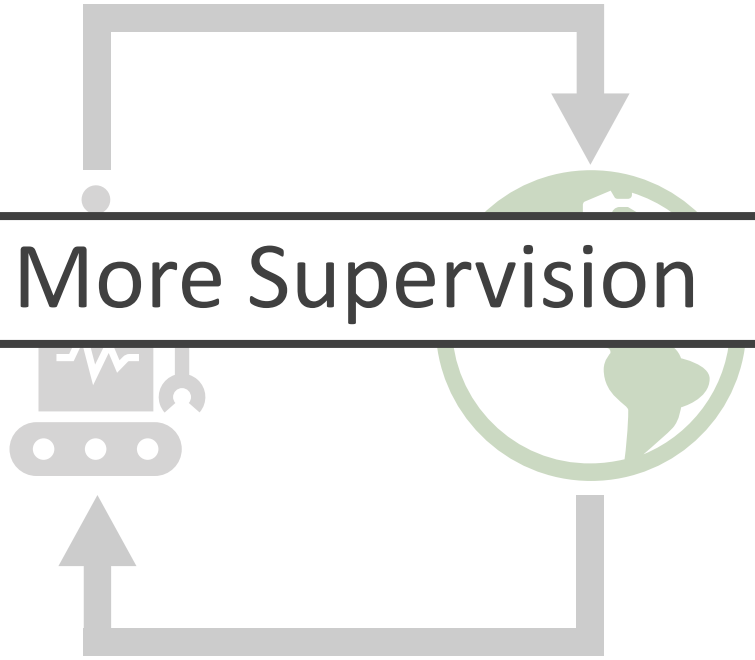
Dog



Dog

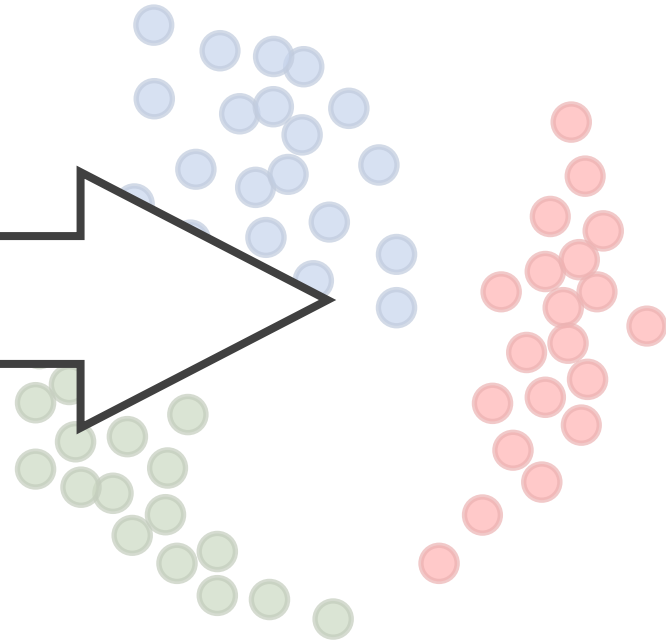
Reinforcement Learning

$\{(\mathbf{x}_i, y_i, r_i)\}$



Unsupervised Learning

$\{\mathbf{x}_i\}$

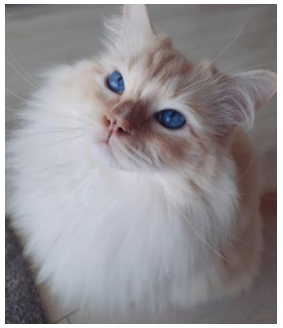


More Supervision

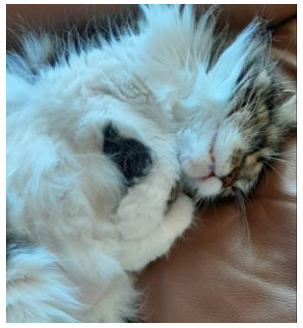
ML Paradigms

Supervised Learning

$\{(\mathbf{x}_i, y_i)\}$



Cat



Cat

Dog

Dog

Reinforcement Learning

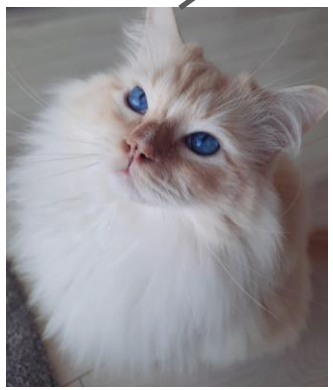
$\{(\mathbf{x}_i, y_i, r_i)\}$

Unsupervised Learning

$\{\mathbf{x}_i\}$

Supervised Learning

$$\{(\mathbf{x}_i, y_i)\}$$



"Cat"

Supervised Learning

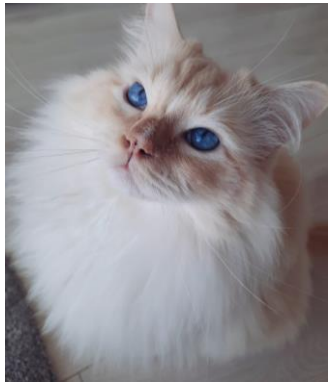
$$\{(\mathbf{x}_i, y_i)\}$$

"Dog"

Supervised Learning

$$\{(\mathbf{x}_i, y_i)\}$$

$$f(y_i|\mathbf{x}_i)$$



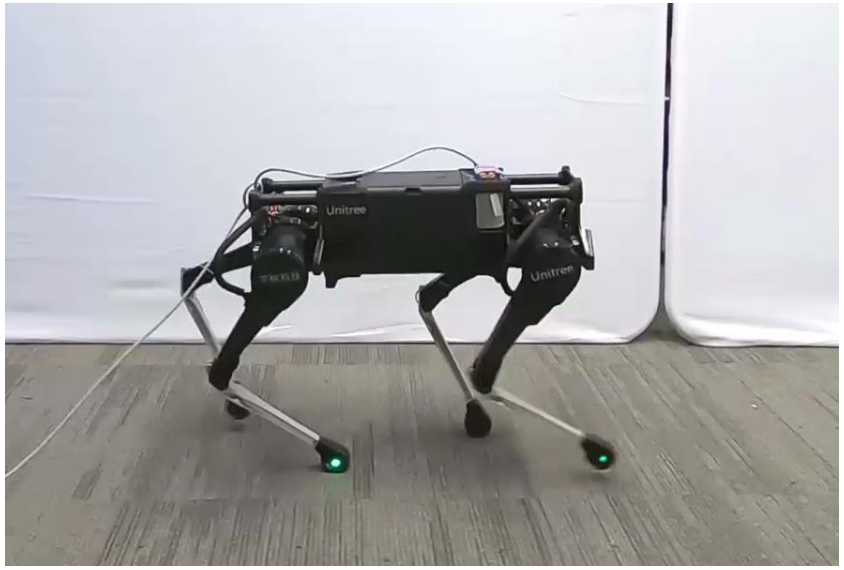
f

“Cat”

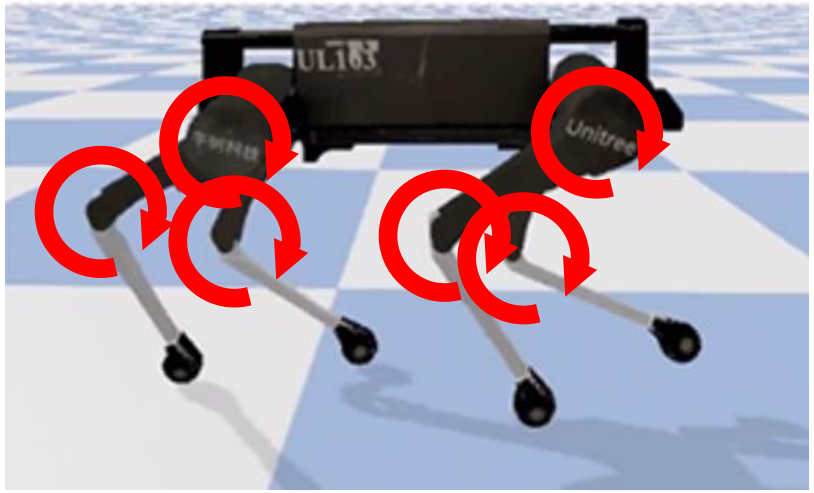
Supervised Learning

$$\{(\mathbf{x}_i, y_i)\}$$

Robot State



Motor Commands



ML Paradigms

Supervised Learning

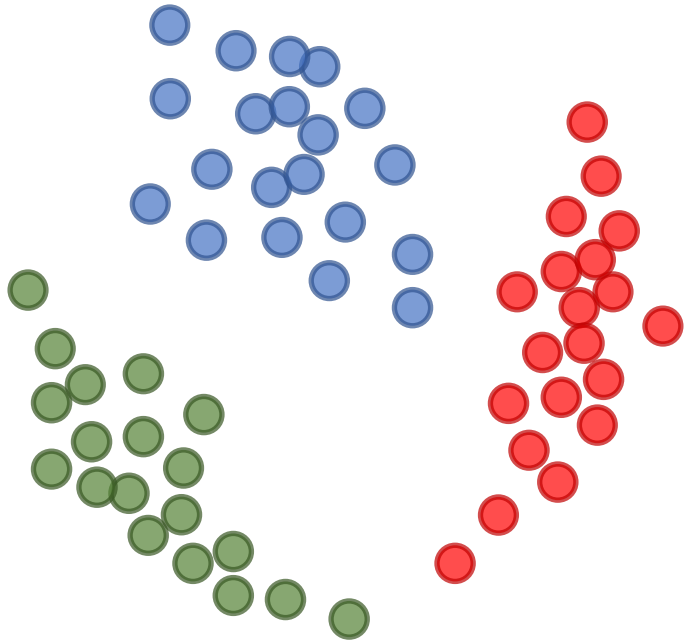
$\{(\mathbf{x}_i, y_i)\}$

Reinforcement Learning

$\{(\mathbf{x}_i, y_i, r_i)\}$

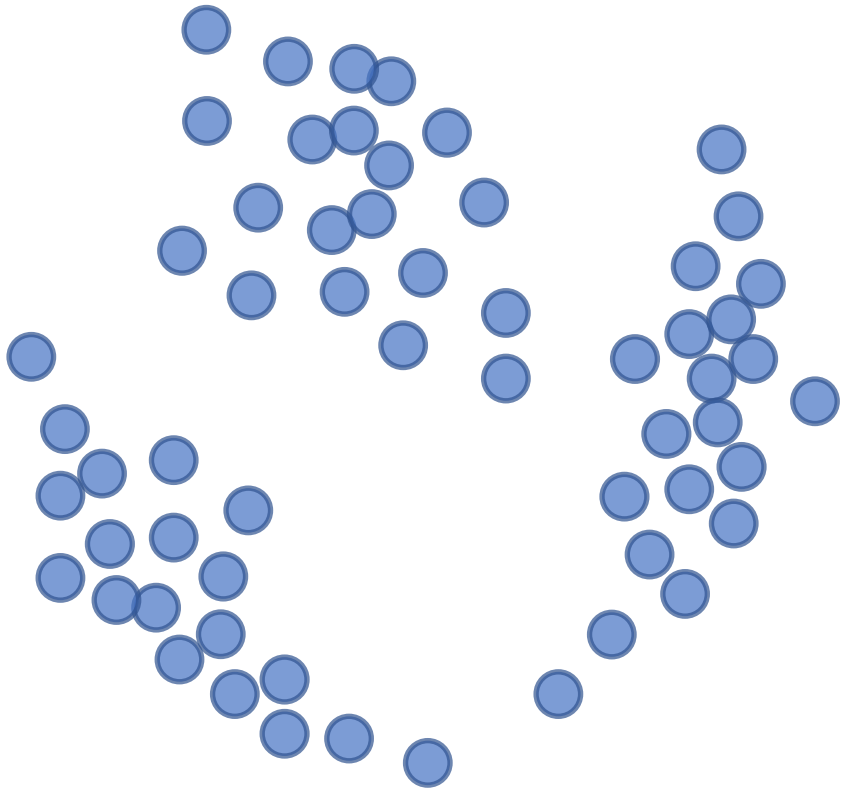
Unsupervised Learning

$\{\mathbf{x}_i\}$



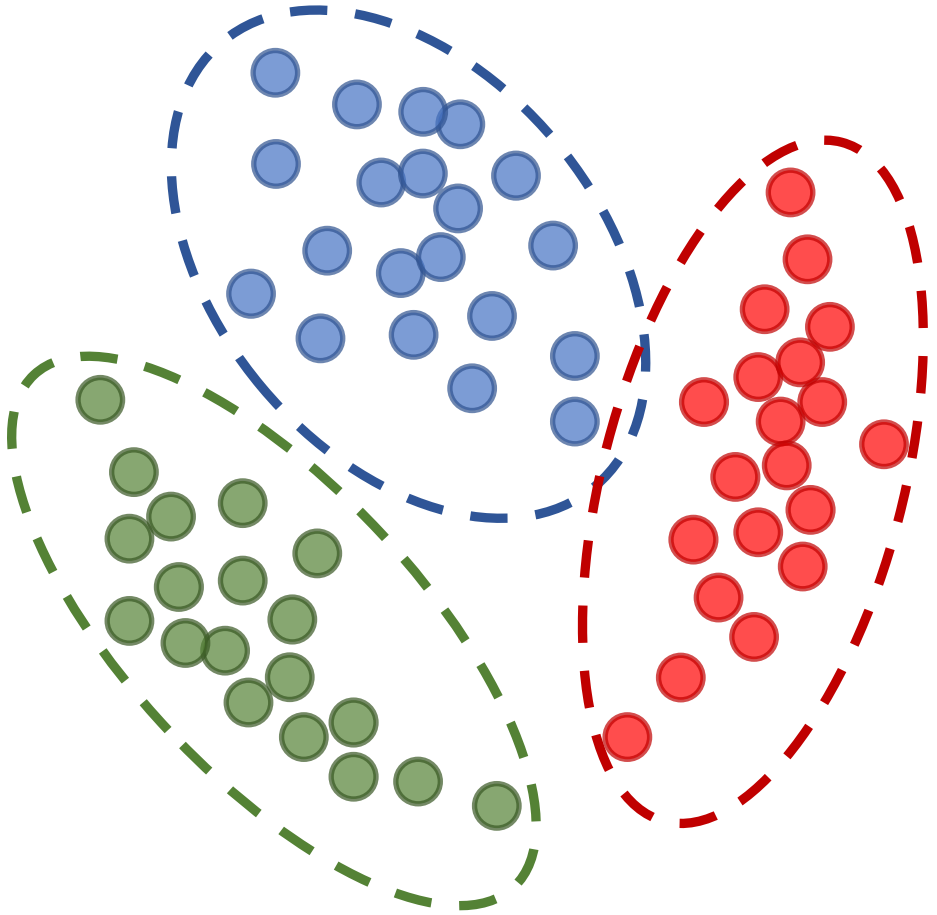
Unsupervised Learning

$$\{\mathbf{x}_i\}$$



Unsupervised Learning

$$\{\mathbf{x}_i\}$$



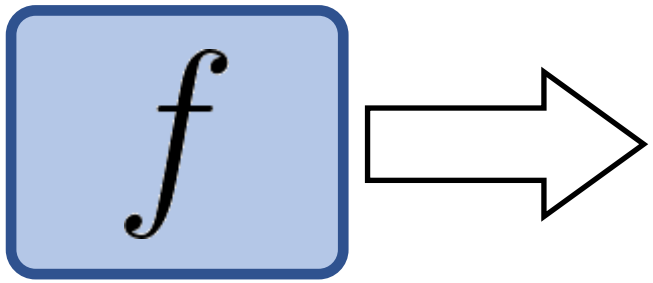
Unsupervised Learning

$$\{\mathbf{x}_i\}$$

Unsupervised Learning

$$\{\mathbf{x}_i\}$$

$$f(\mathbf{x}) \approx p(\mathbf{x})$$



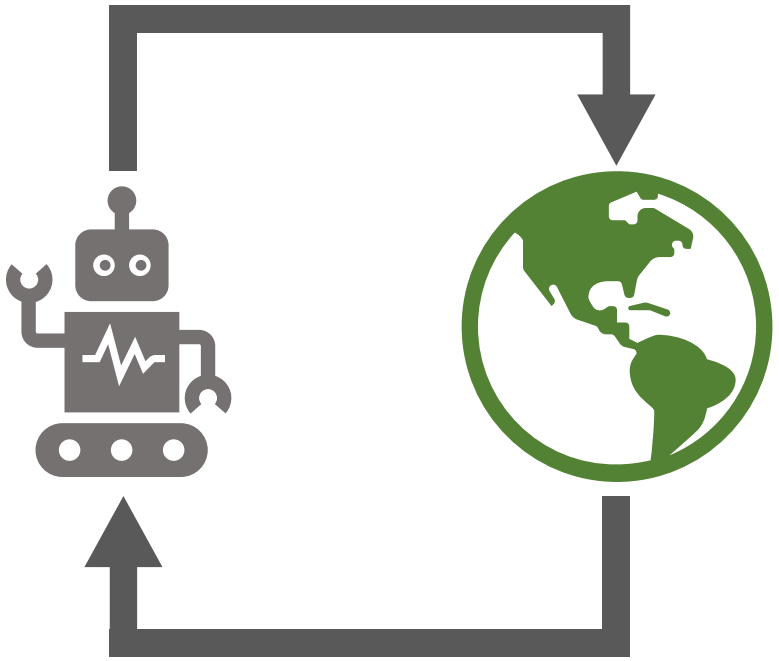
ML Paradigms

Supervised Learning

$\{(\mathbf{x}_i, y_i)\}$

Reinforcement Learning

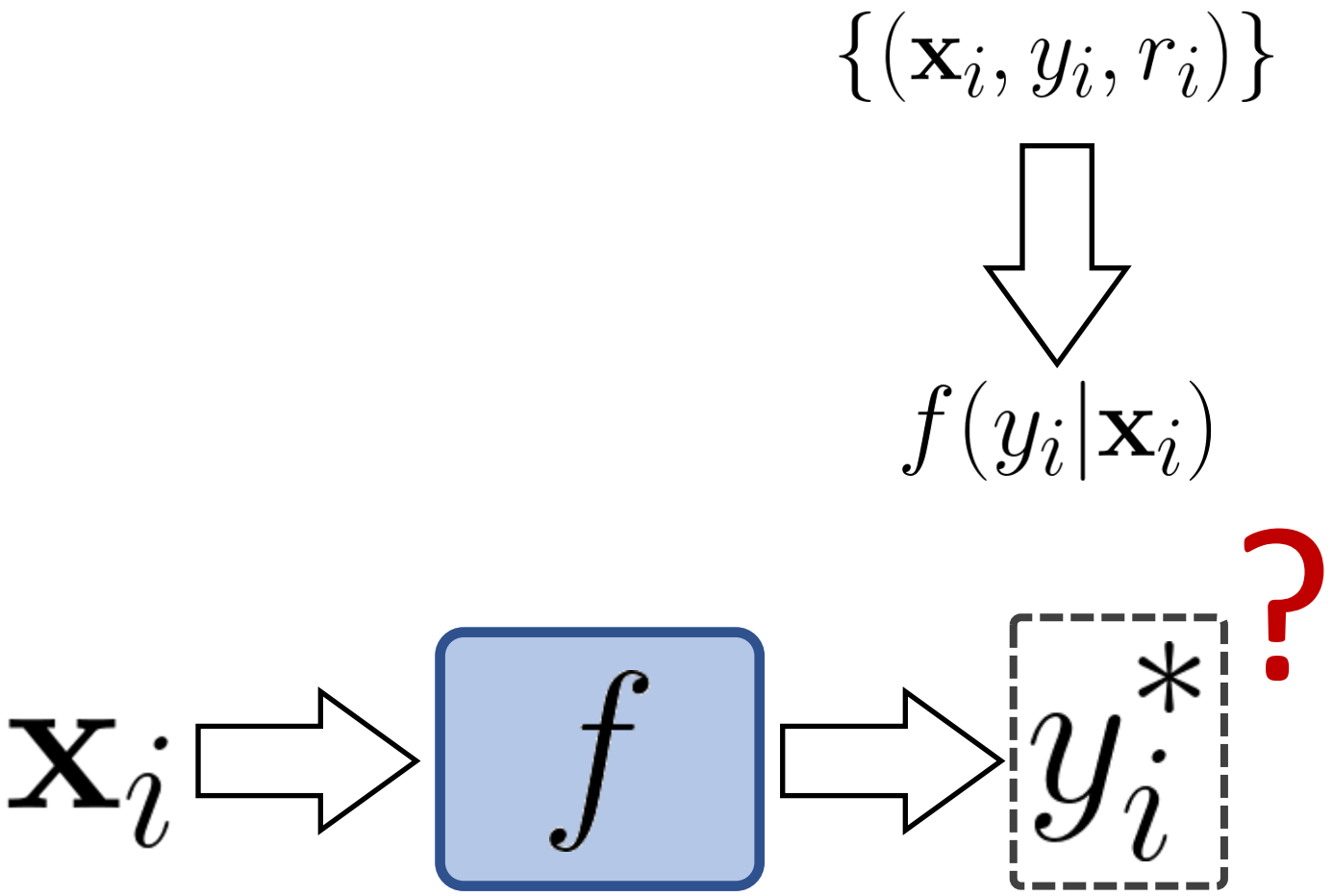
$\{(\mathbf{x}_i, y_i, r_i)\}$



Unsupervised Learning

$\{\mathbf{x}_i\}$

Reinforcement Learning

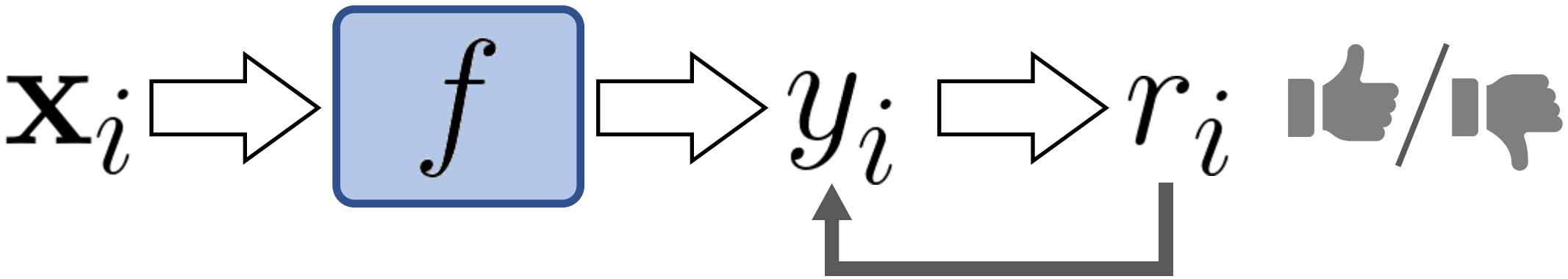


Reinforcement Learning

$$\{(\mathbf{x}_i, y_i, r_i)\}$$

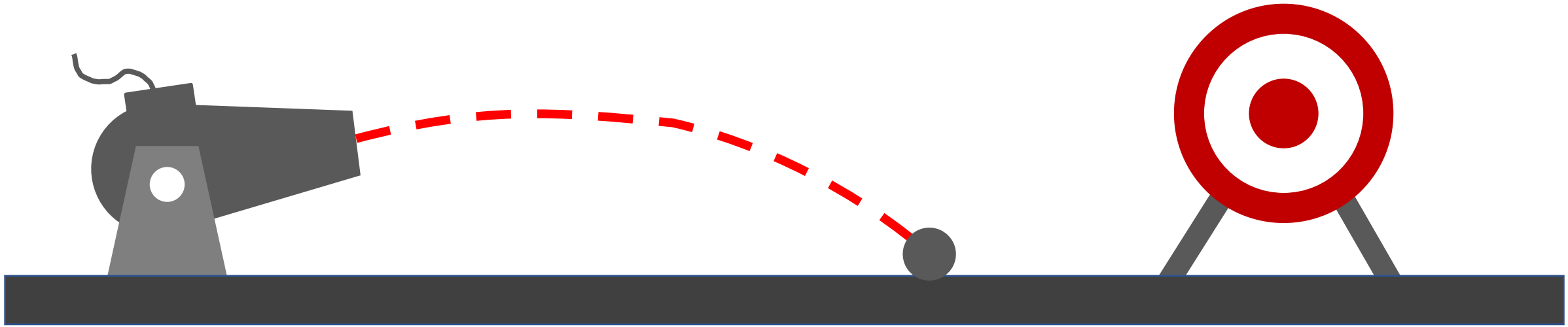
Score/Reward

$$f(y_i|\mathbf{x}_i)$$



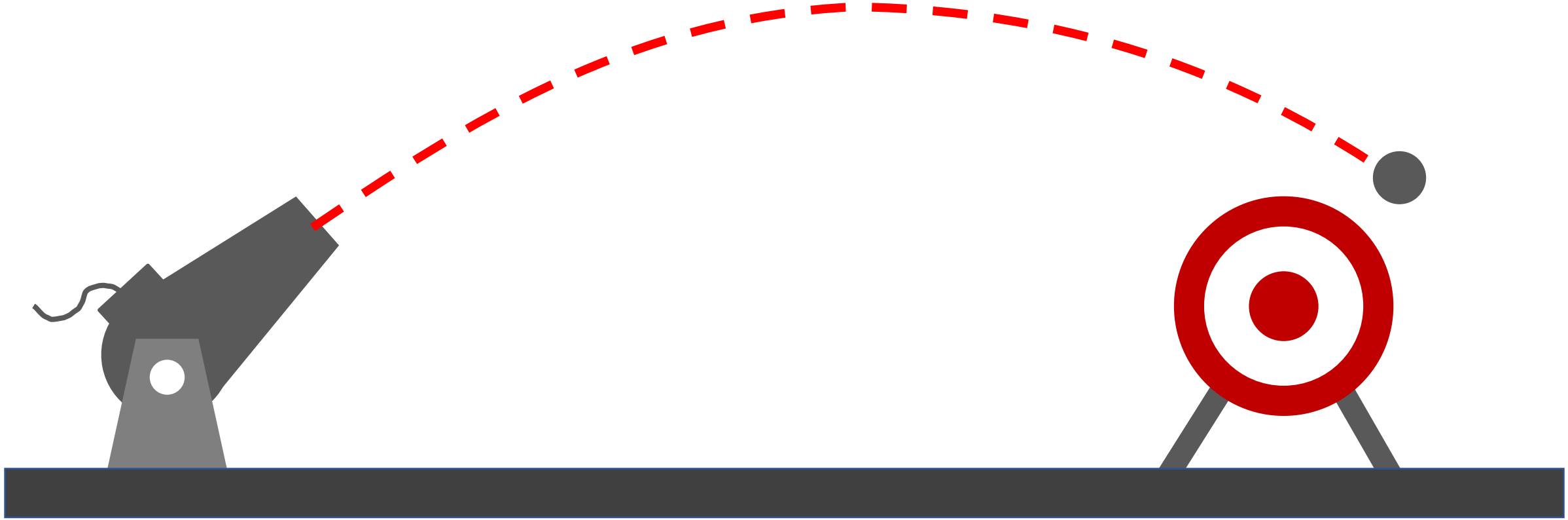
Reinforcement Learning

- Learning through trial-and-error



Reinforcement Learning

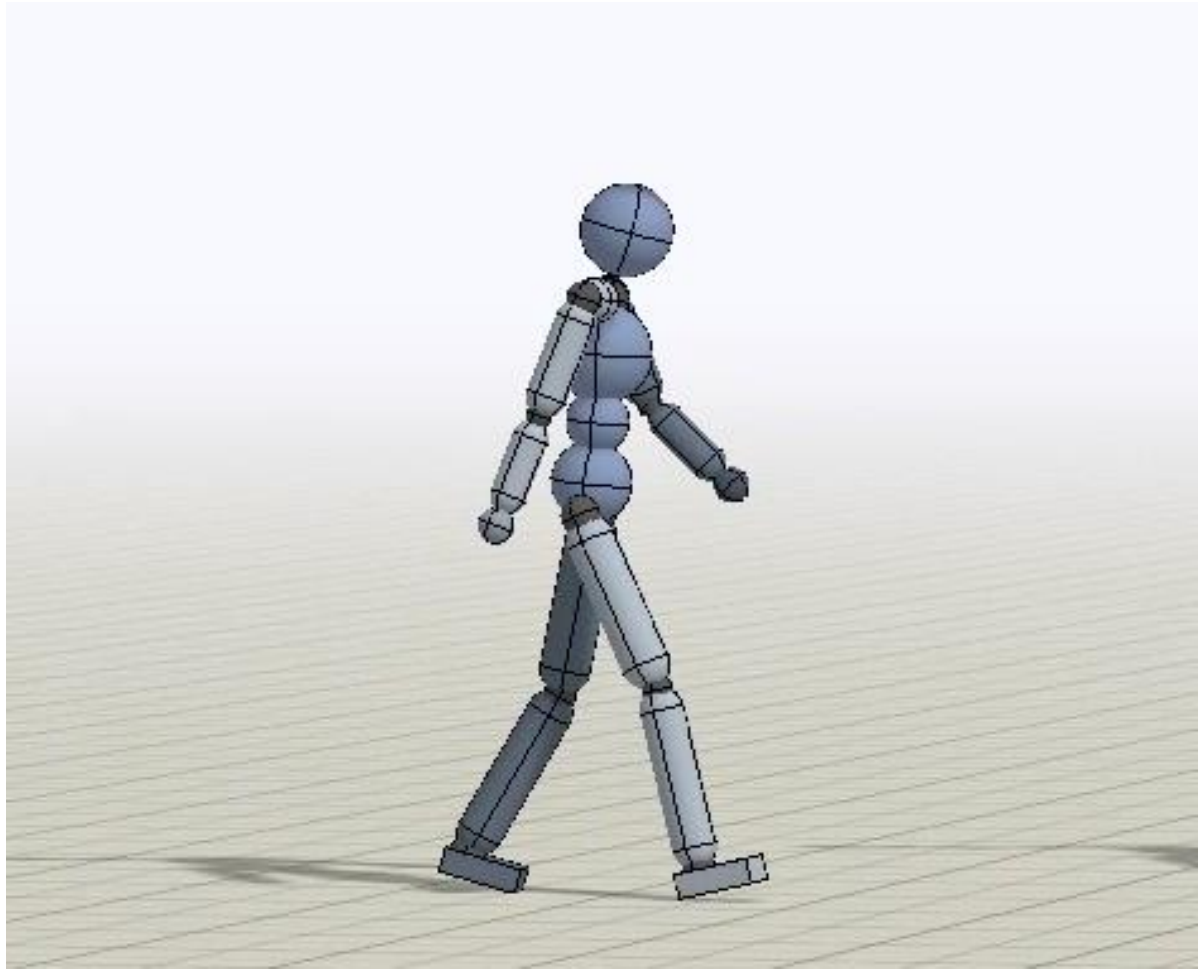
- Learning through trial-and-error



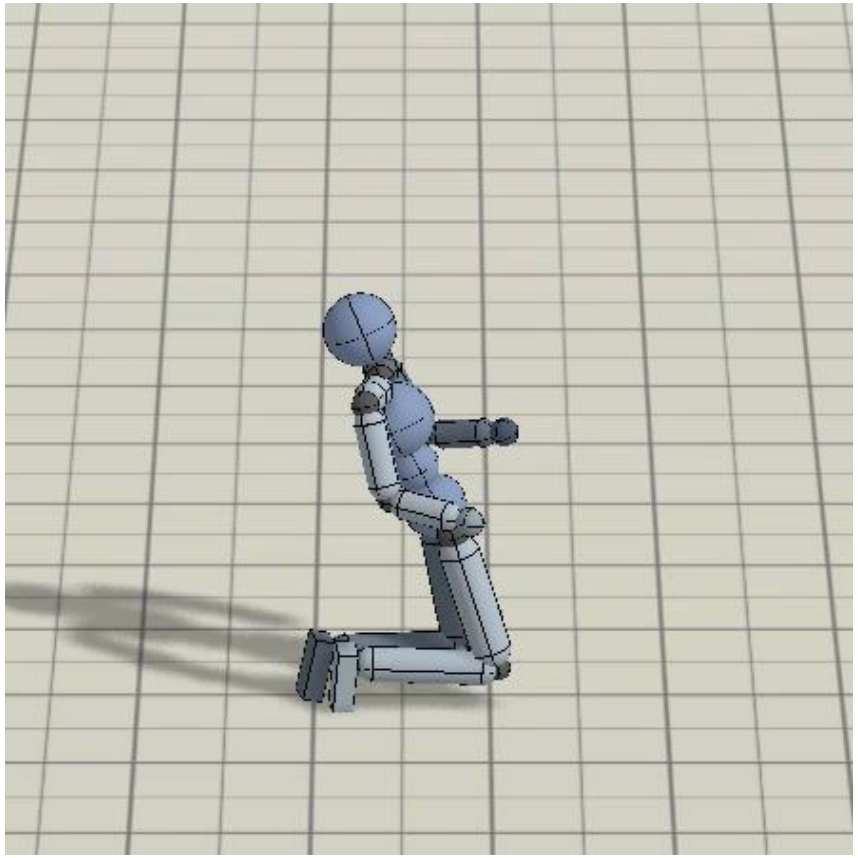
Reinforcement Learning

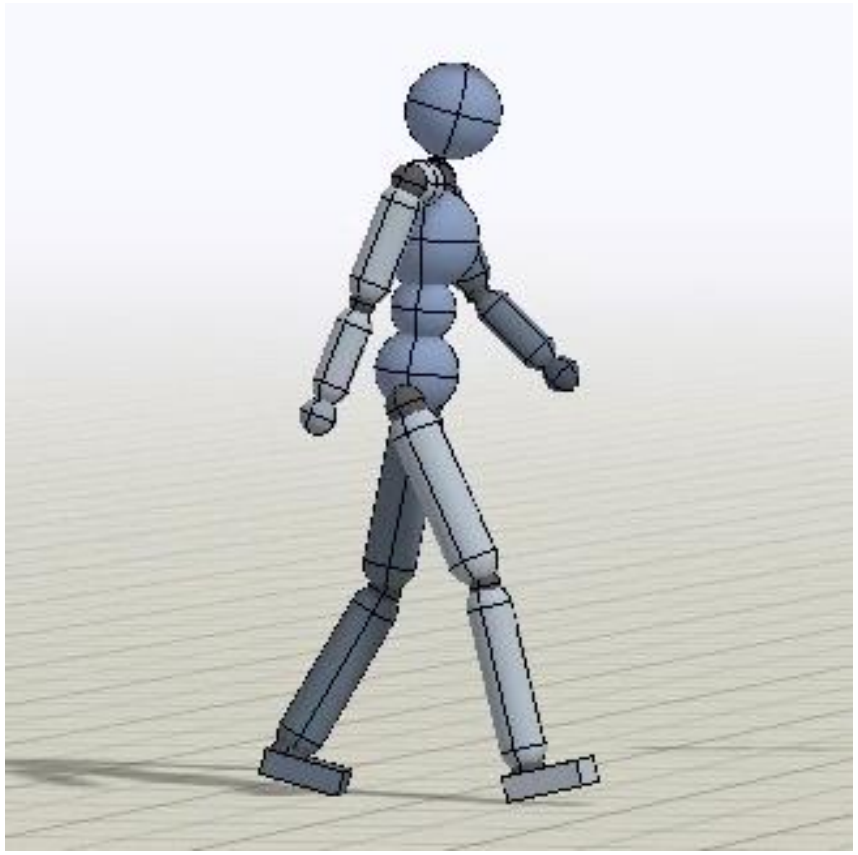
- Learning through trial-and-error

Reinforcement Learning

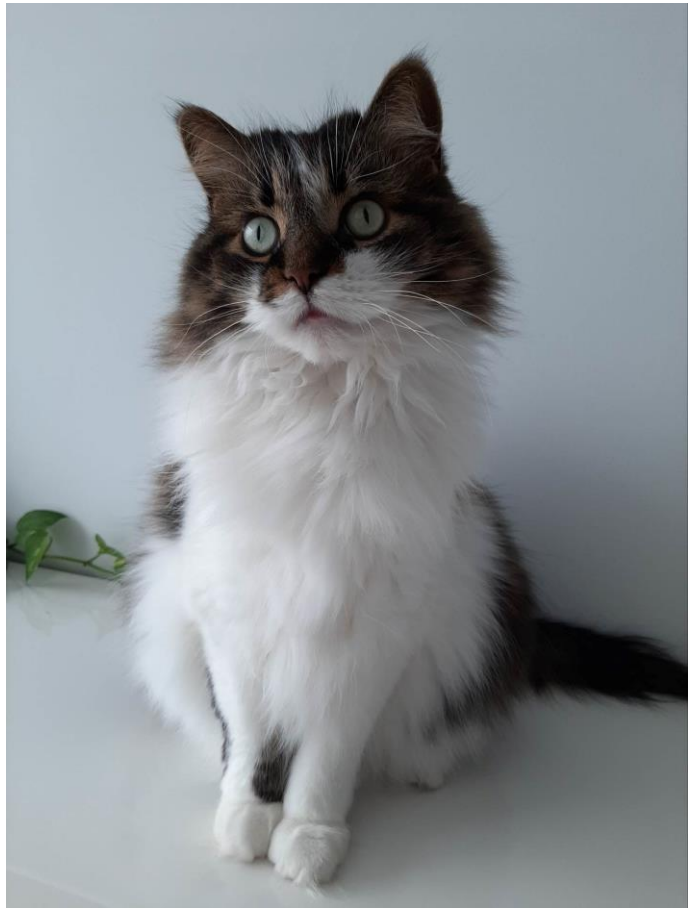


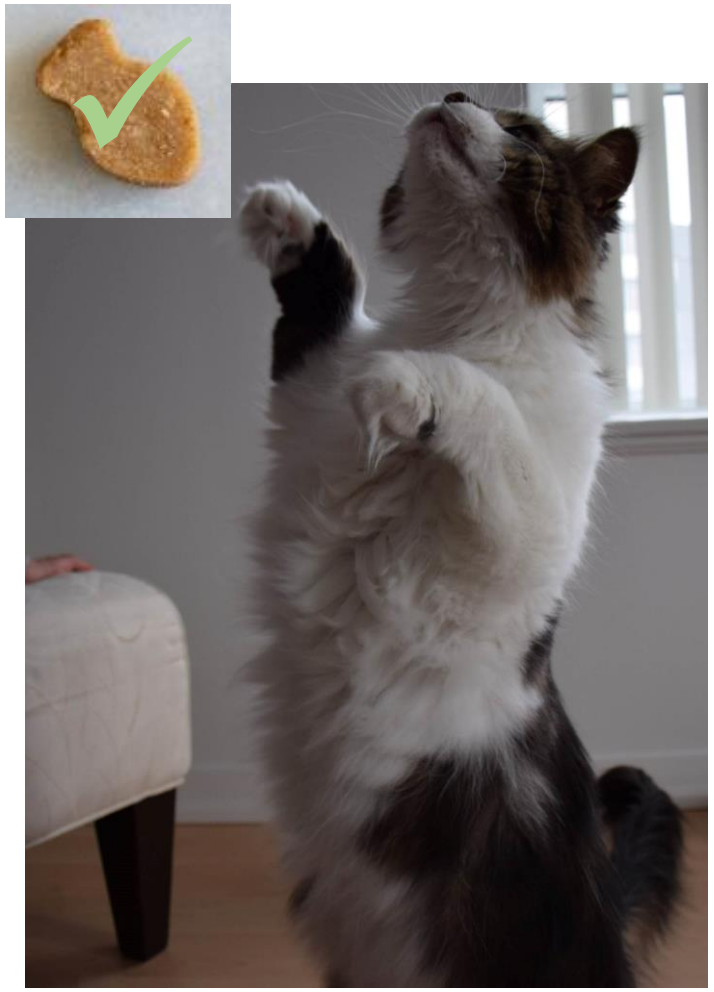
Reinforcement Learning

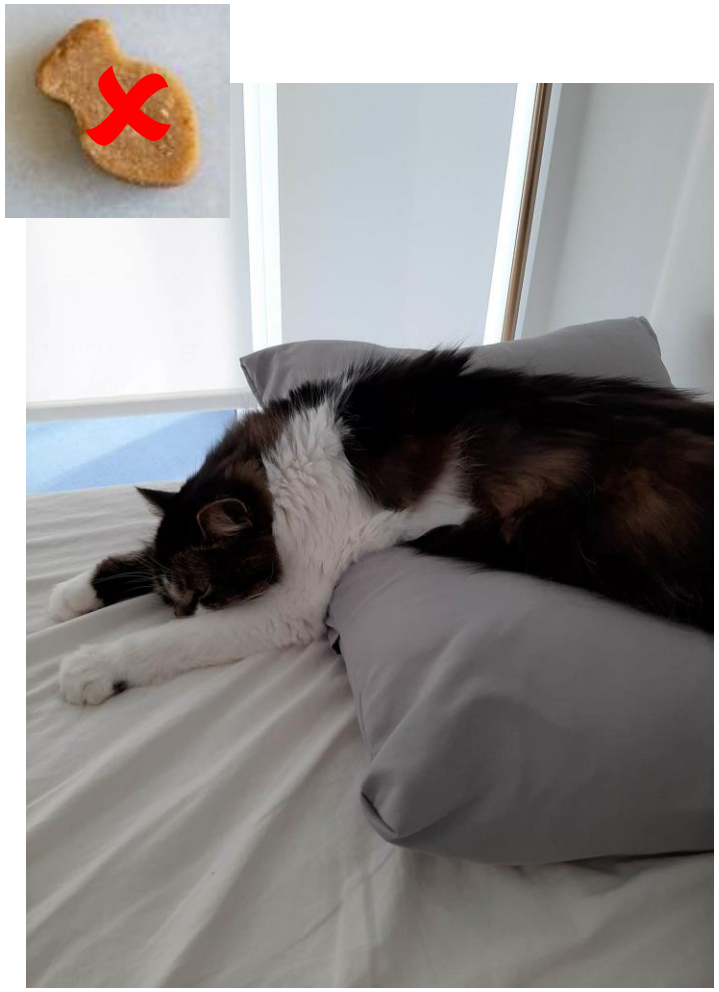




Reinforcement Learning







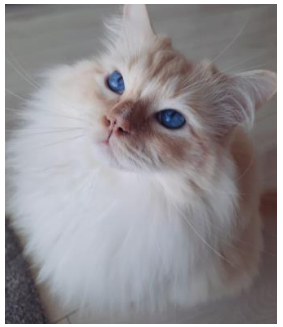
Reinforcement Learning

[AlphaGo 2016]

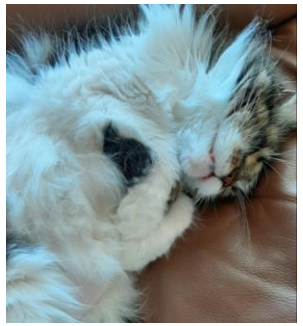
Data Sources

Supervised Learning

$$\{(\mathbf{x}_i, y_i)\}$$



Cat



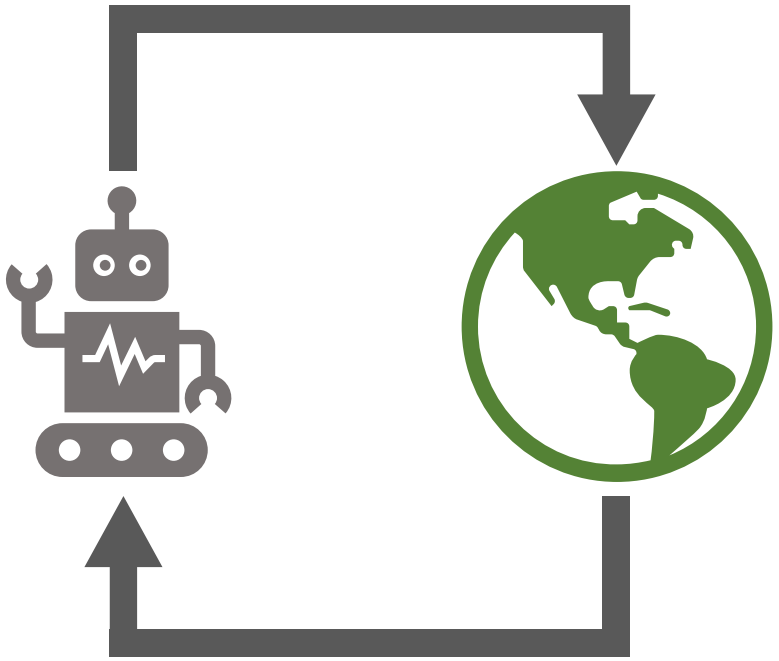
Cat

Dog

Dog

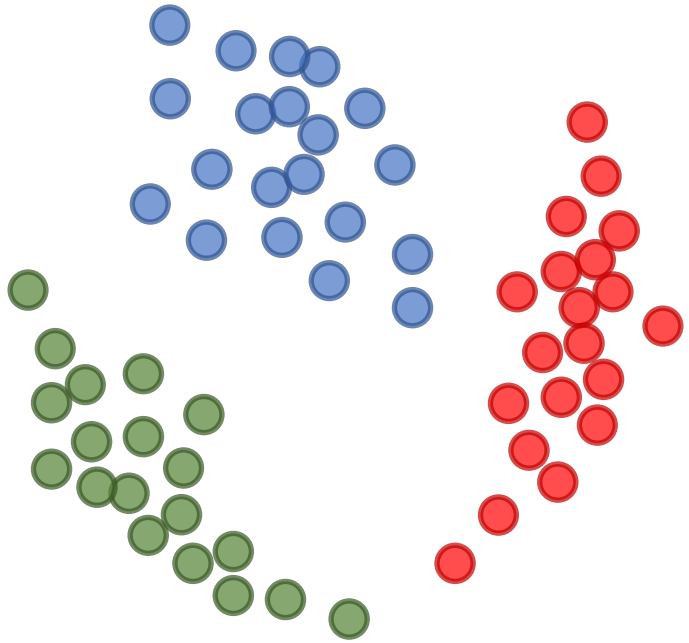
Reinforcement Learning

$$\{(\mathbf{x}_i, y_i, r_i)\}$$



Unsupervised Learning

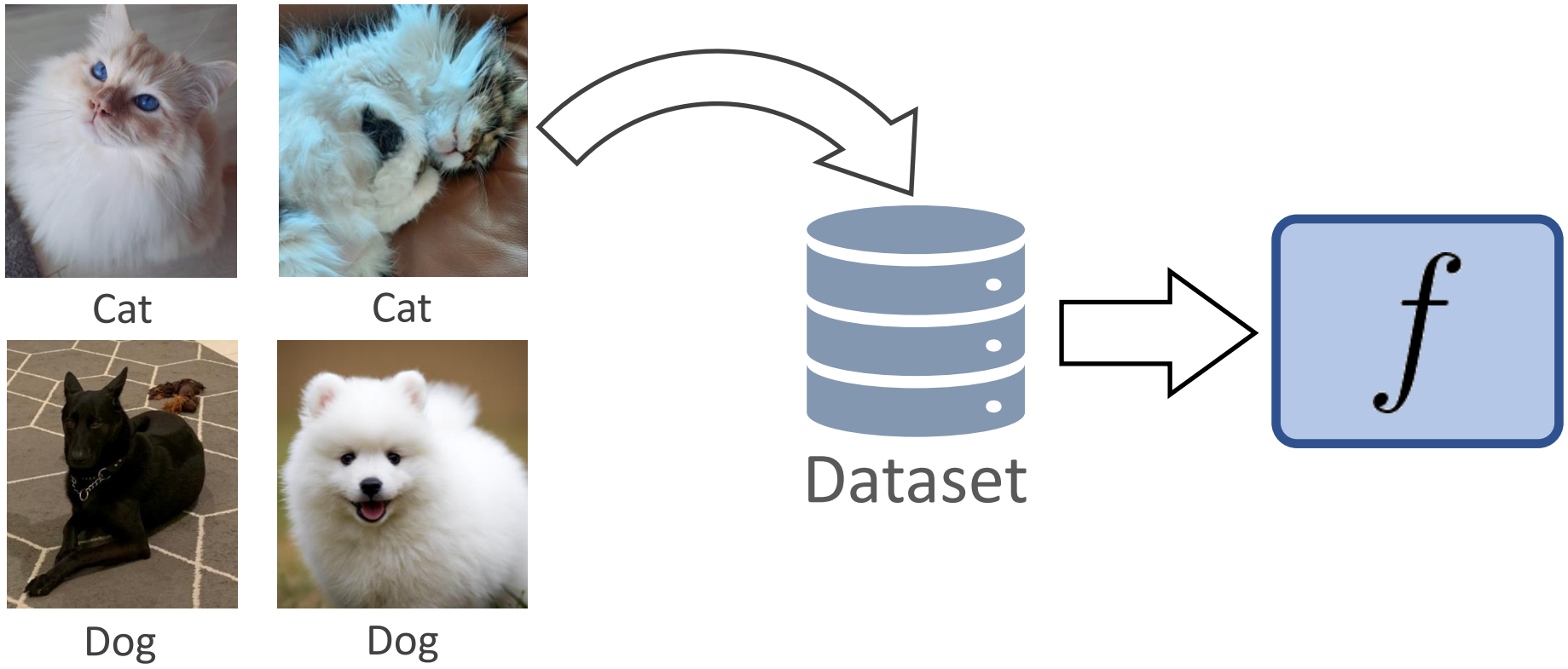
$$\{\mathbf{x}_i\}$$



Passive Learning

Passive Learning: Agent is given a fixed dataset to learn from

- Agent passively observes the world
- does not affect its environment



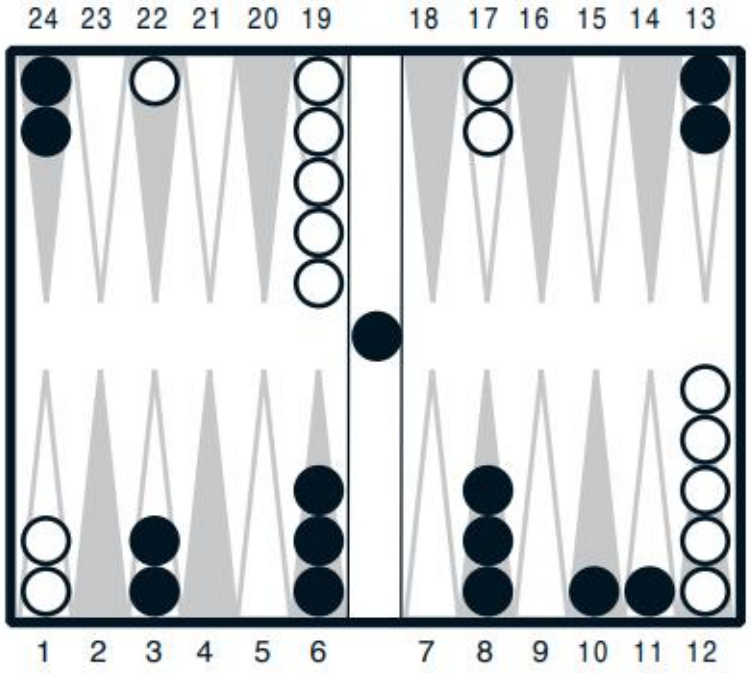
Active Learning

Active Learning: Agent collects its own data

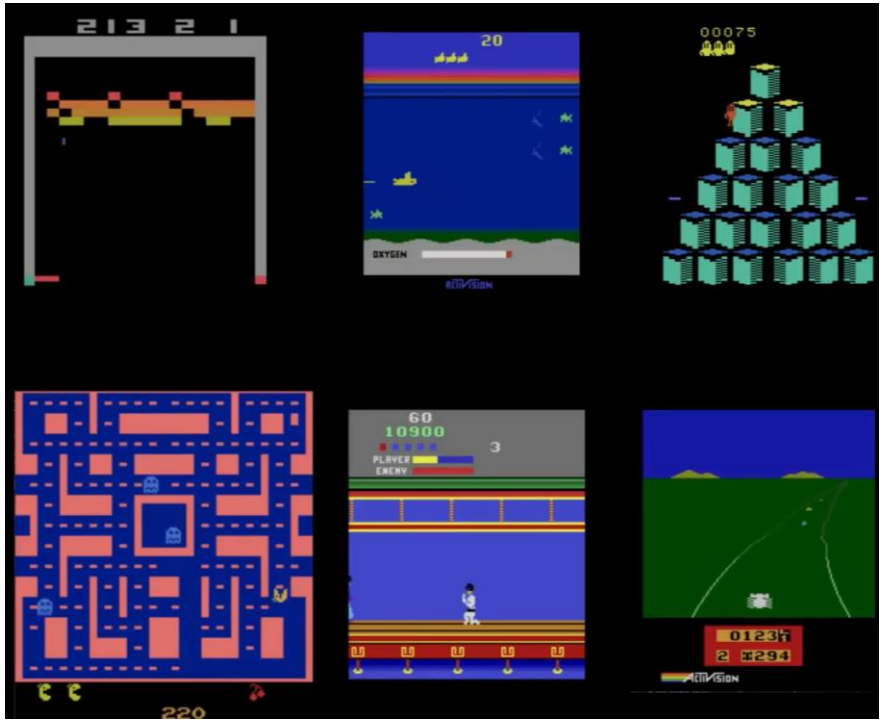
- Agent interact and affects its environment
- Data depends on the agent's behaviors

Applications

Games



[Tesauro 1995]

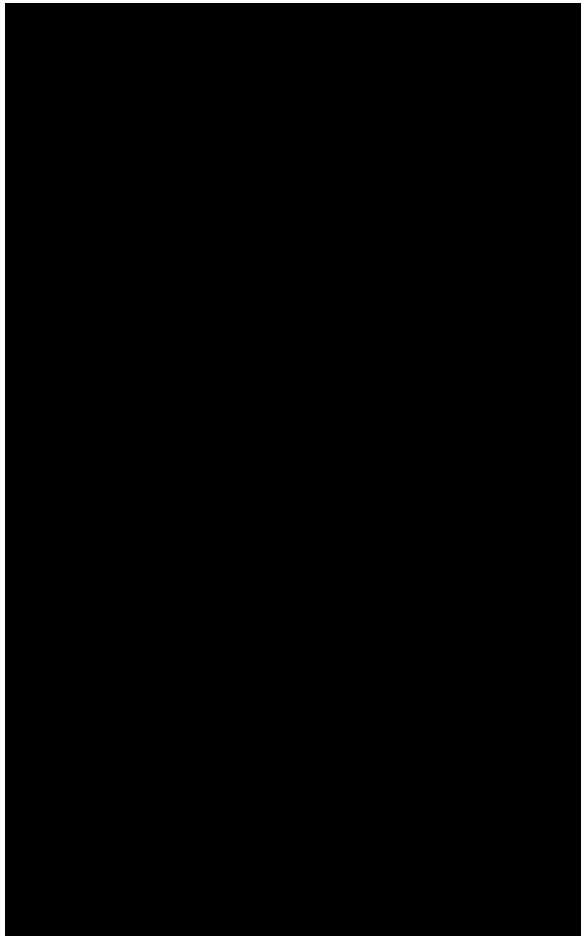


[Mnih et al. 2015]

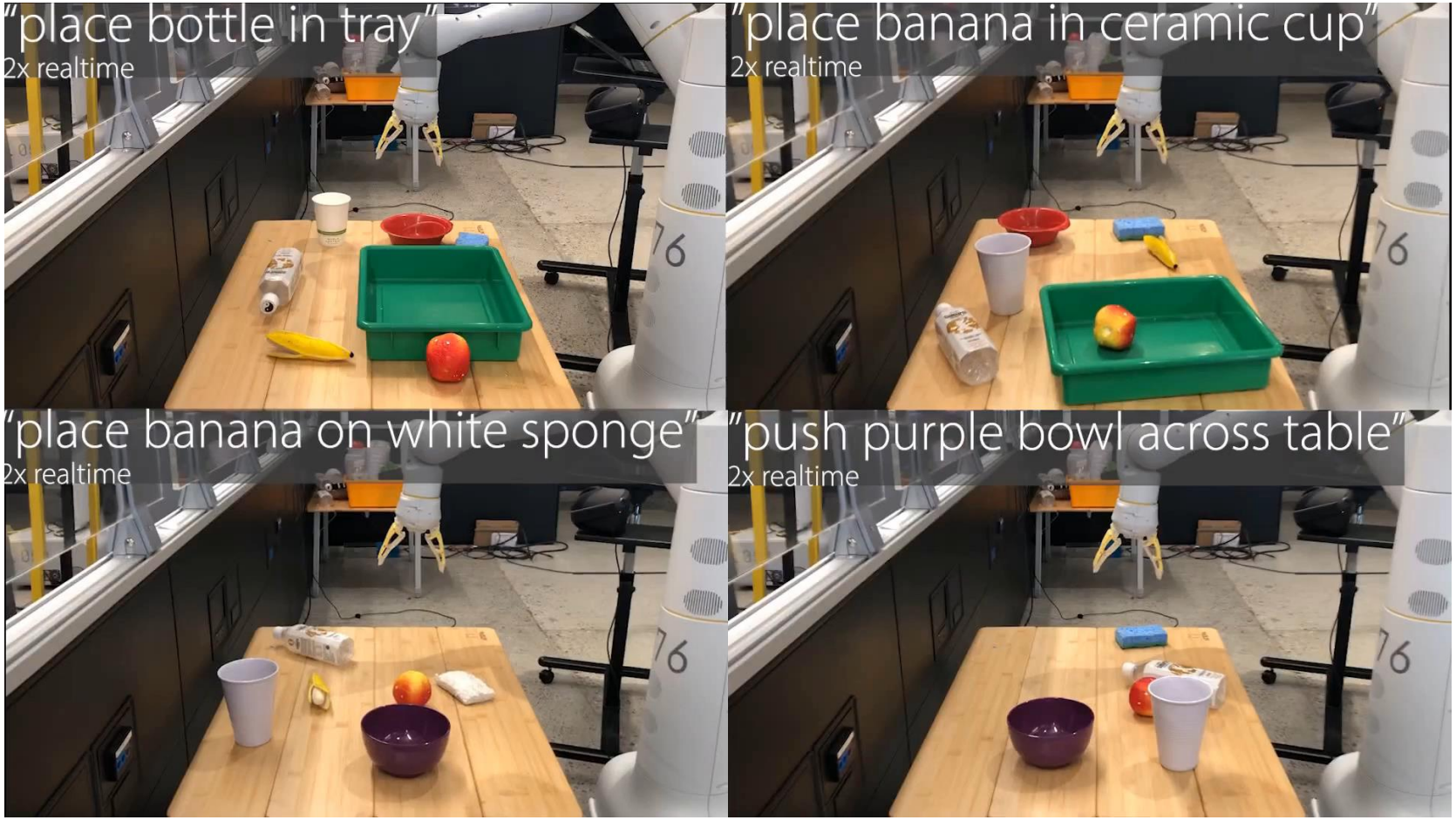
[Silver 2017]

Grandmaster Level in StarCraft II Using Multi-Agent Reinforcement Learning
[Vinyals 2019]

Robotic Manipulation



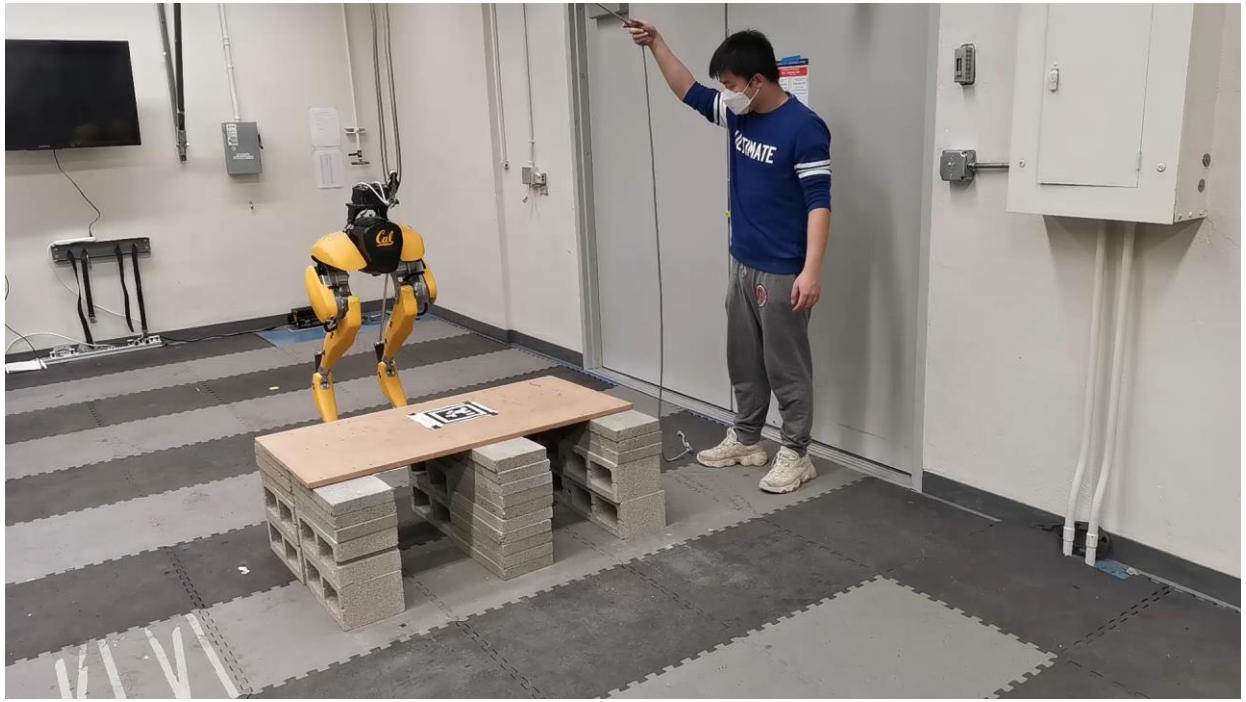
[Nagabandi et al. 2019]



[Jang et al. 2021]

Robotic Locomotion

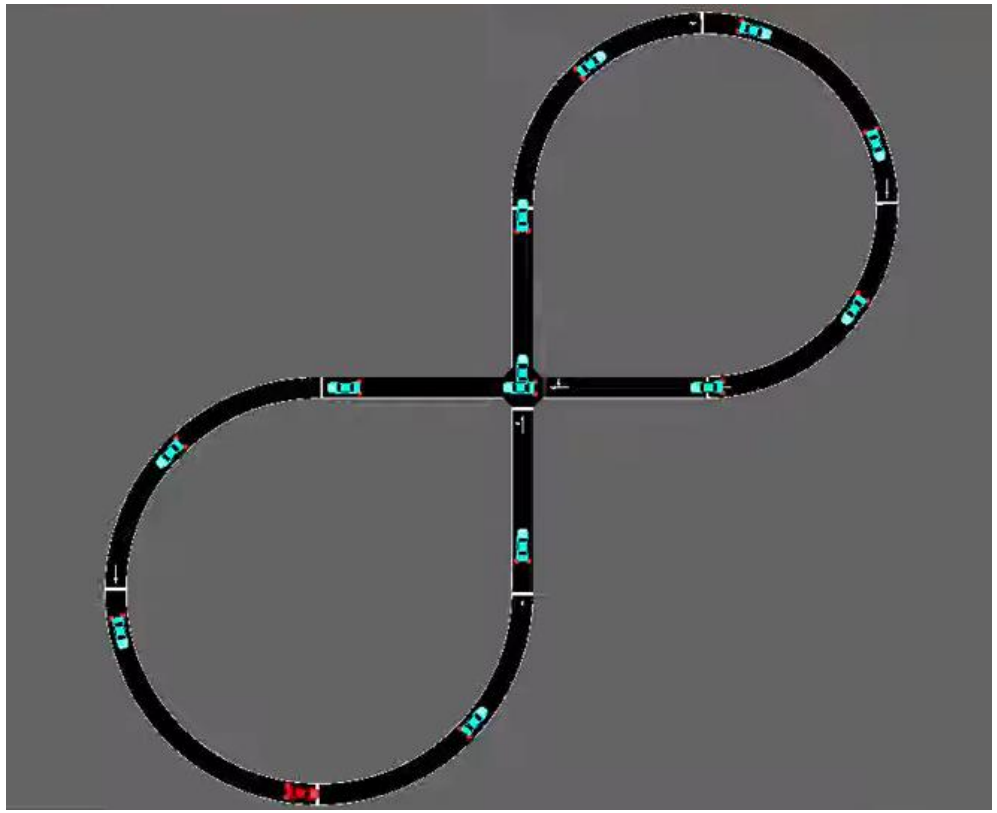
[Miki et al. 2022]



[Li et al. 2023]

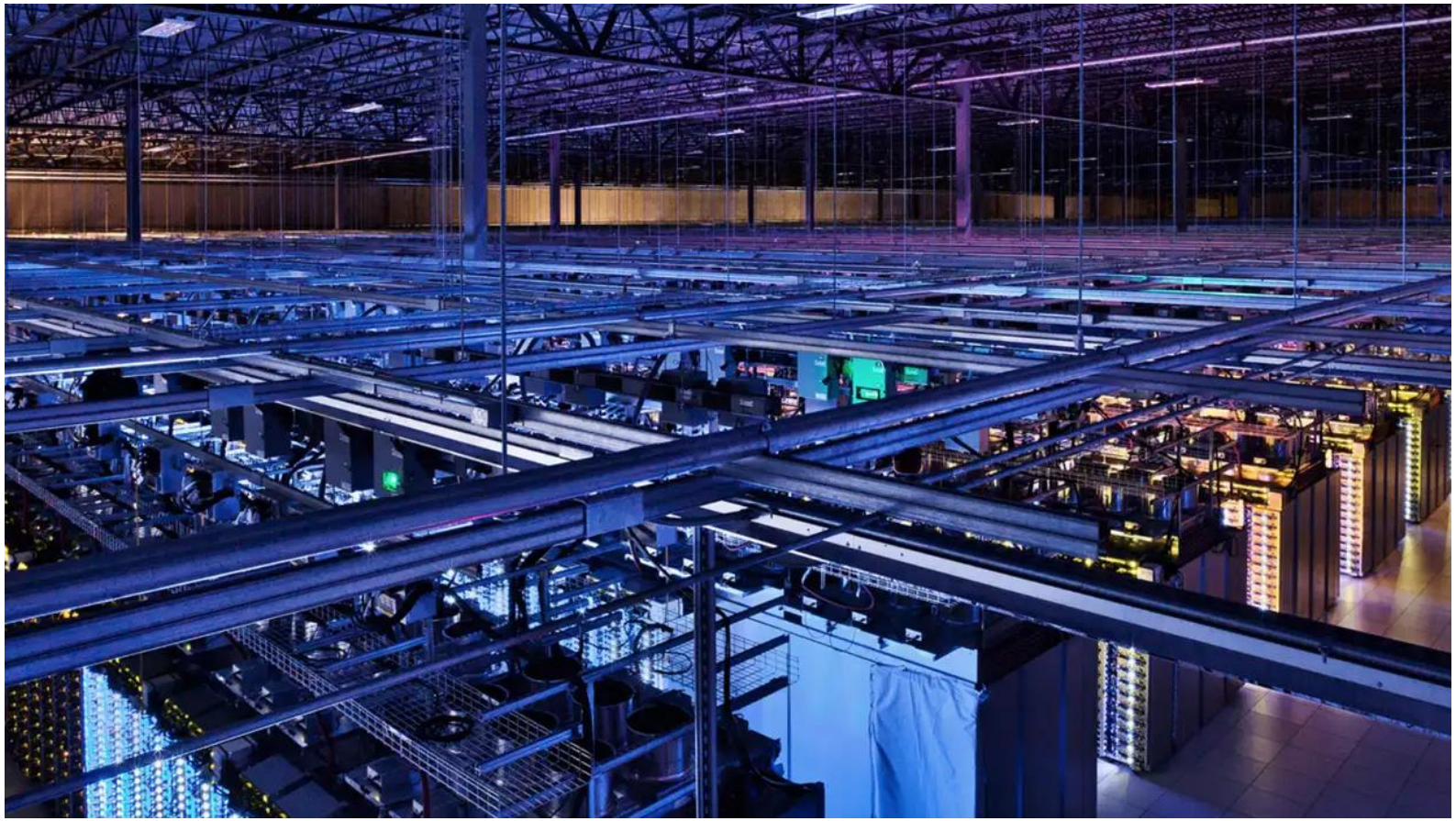
Autonomous Driving

[Bojarski et al. 2016]



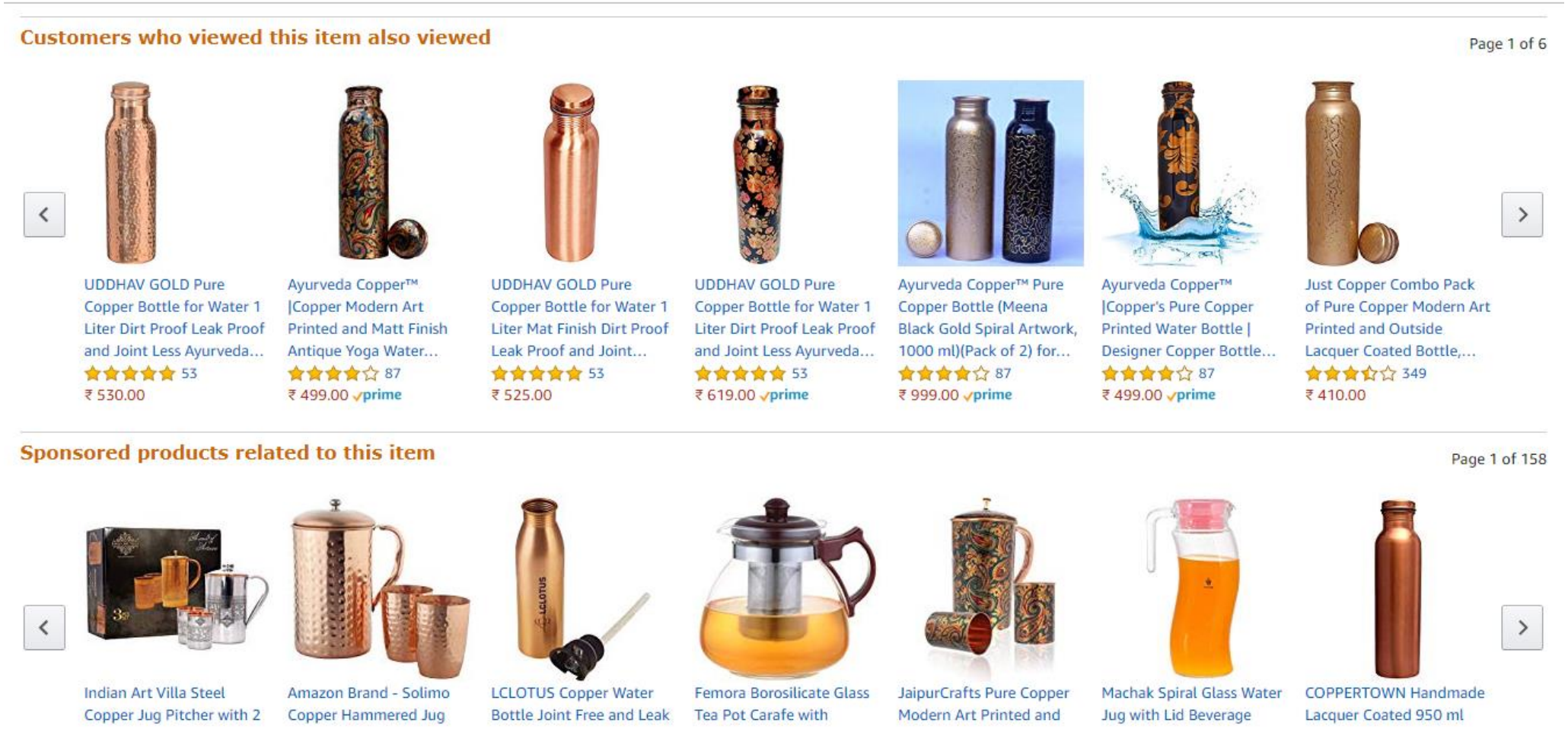
[Wu et al. 2021]

Energy Conservation



Safety-First AI for Autonomous Data Centre Cooling and Industrial Control [Gamble and Gao 2018]

Recommendation Systems



Reinforcement Learning to Optimize Long-term User Engagement in Recommender Systems [Zou et al. 2019]

Computer Graphics

ASE: Large-Scale Reusable Adversarial Skill Embeddings for Physically Simulated Characters
[Peng et al. 2022]

Logistics

Preliminaries

- There will be **a lot** of math
  - Probability theory
  - Calculus
  - Linear algebra
- Machine learning
  - Neural networks
  - Optimization
  - Supervised learning
  - Unsupervised learning
- Programming
  - Python
  - PyTorch

Lectures

00: Introduction

01: MDP

02: Policy Evaluation

03: Behavioral Cloning

04: Policy Search

05: RL Algorithms

06: Policy Gradient

07: Q-Learning

08: Actor-Critic Algorithms

09: Model-Based RL

10: On-Policy vs. Off-Policy Algorithms

11: Advance Policy Gradient

12: Advance Q-learning

13: Exploration

14: Unsupervised RL

15: Imitation Learning

16: Domain Transfer

17: Offline RL

*Tentative

Grading

- 3 programming assignments (10% each)
- Paper presentation (20%)
- Course project (50%)
  - Proposal (10%)
  - Presentation (20%)
  - Report (20%)
- No exams

Paper Presentation

- Present an RL-related paper

- Groups 3-4 (depending on class size)

Course Project

- Apply reinforcement learning to solve an interesting problem
  - No board games
  - No Atari games
  - No standard benchmark problems (OpenAI gym, DeepMind Control Suite)
- Groups 3-4 (depending on class size)
- 1-2 page proposal due in mid June
- Project presentations at the end of the semester
- Project report due at the end of the semester

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CMPT 729 G1: Discussion Forum

[Forum Summary]

[New Thread]

Nothing posted yet.

[Discussion forum identities]

[Activity digest]

Unanswered Questions

None

A question is considered "answered" if (1) an instructor/TA has replied, (2) an instructor/TA has reacted positively (👍, ❤️, 👏) to a student reply, or (3) the question-asker has marked it answered or reacted positively to a reply.

Unread Activity

None

Search Posts

Search posts:

Office Hours

Jason: Thursday 2-3pm in TASC 9213

Ruiqi: Monday 3-4pm in TASC 8004

Summary

- What is reinforcement learning?
- Applications
- Logistics