Reinforcement Learning: A Practical Introduction

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Orions Systems, Inc / Microsoft
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About Orions Systems Inc

Distributed, **Hierarchical**, **AI and human compute**, video analytics platform for enterprise and intelligence agencies.

- v1: 100% human compute to annotate sports in near real time
    - **Distributed** = many humans in parallel
    - **Hierarchical** = tag start/end of play-> label play, touches -> intent (forced/unforced error)
    - 100k games per year

- v2 added **AI and human compute**
    - Automated training data, real time QA
    - Supports scenarios beyond today's AI capabilities

Acquired by Microsoft, July 2020

- Team, tech joined Dynamics Connected Store group

Dynamics 365 Connected Store

Introduction to Reinforcement Learning (RL)

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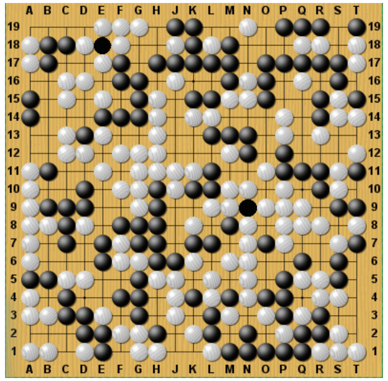
RL vs. Supervised, Un-/semi-supervised Learning

1. RL = an agent ***actively searching*** a dataset
    - The agent’s action at timestep t, impacts observations at future timesteps
    - … In chess, each action changes the environment
    - … In multi-armed bandit, each action changes the information we have about the environment

2. RL is for searching truly massive search spaces

Go has more valid states
than atoms in the universe.



RL is a tool for exploring massive search spaces

Examples of Real-world Deployments

Self driving (Wayve, etc.)

Robotics (Covariant, etc.)

Industrial Control (Microsoft, Google, etc)

+ Financial Tech

+ Search

+ Route Optimization

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Technical Overview of Reinforcement Learning

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Technical Overview of RL

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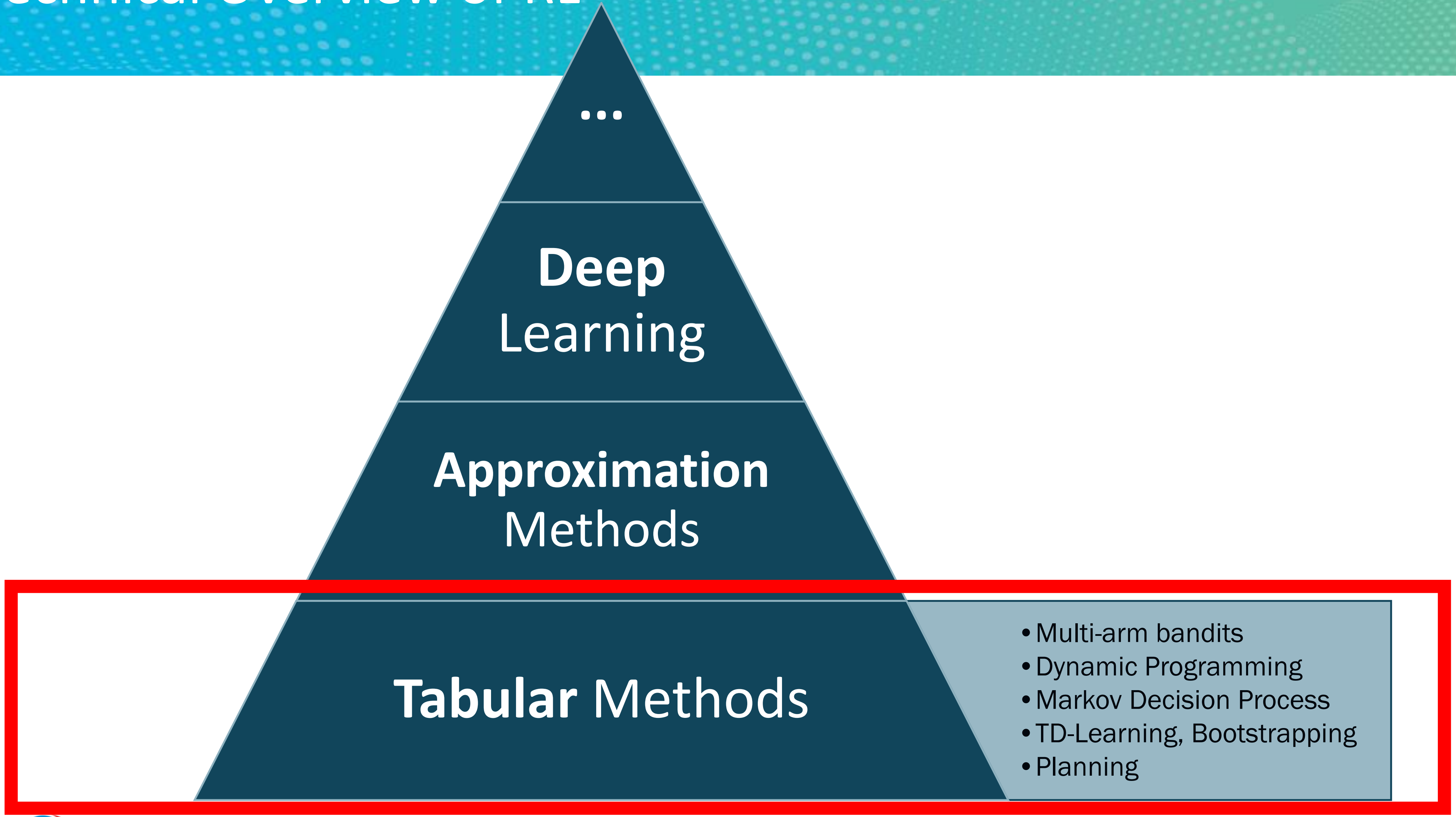
Deep Learning

Approximation Methods

Tabular Methods

Technical Overview of RL



Technical Overview - **Tabular Solution Methods**

Multi-armed Bandits

... payout %	... payout %	... payout %

Don't know payout ratio.

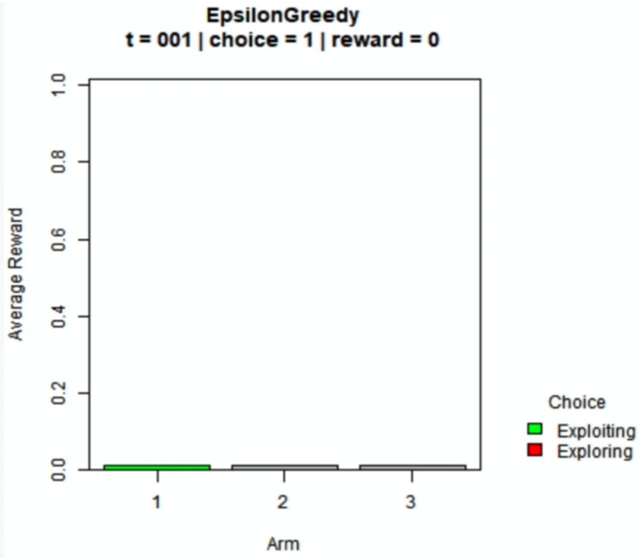
Each action costs $1

Exploration = search (choose a random arm)
vs
Exploitation = choose best arm

Technical Overview - **Tabular Solution Methods**

Multi-armed Bandits

?



Don't know payout ratio.

Each action costs $1

Exploration = search (choose a random arm)
vs
Exploitation = choose best arm

Epsilon Greedy

Example: e=0.1

If random value > e, Exploit else Explore

Note: Used in DQN and many RL algos

Technical Overview - **Tabular Solution Methods**

Multi-armed Bandits

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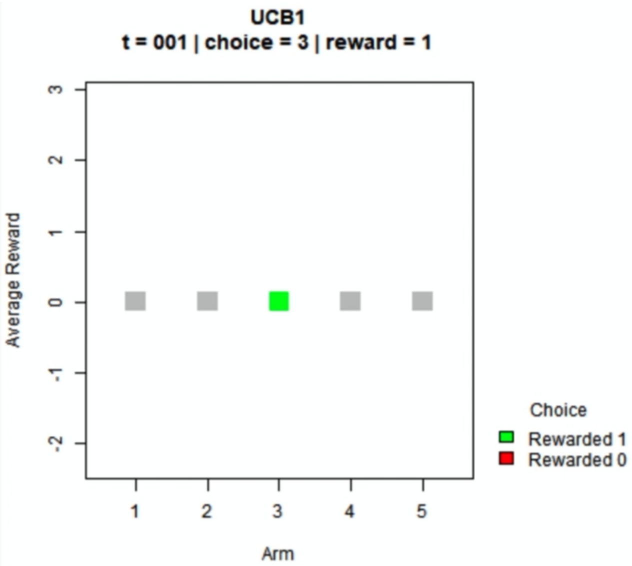


Upper Confidence Bounds

Choose arm with highest potential return
(based on confidence)

or Random If 2+ arms have same score

Note: Used in
AlphaZero / MuZero

Technical Overview - **Tabular Solution Methods**

Finite Markov Decision Processes

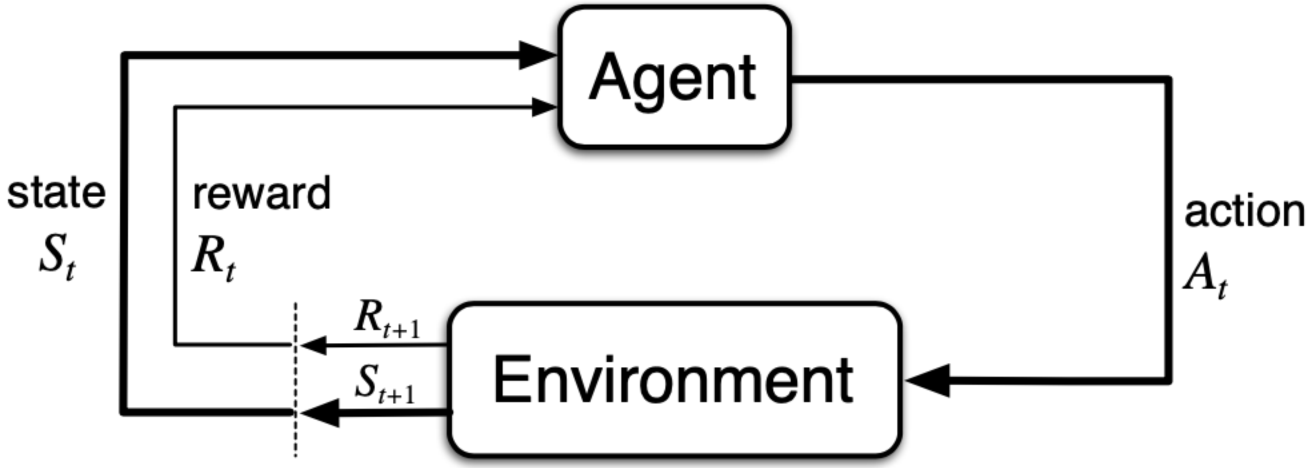


Figure 3.1: The agent–environment interaction in a Markov decision process.

Finite Markov Decision Processes – Blackjack

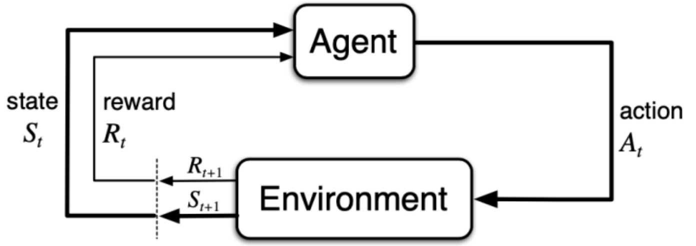
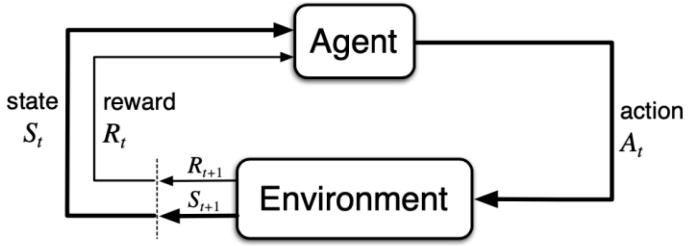


Figure 3.1: The agent–environment interaction in a Markov decision process.

Finite Markov Decision Processes – Blackjack

200 States:
- Player Hand 12 to 21
- Dealer Showing A to 10
- Player Ace / No Ace
- = 10x10x2

2 Actions:
- Hit or Stick



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Finite Markov Decision Processes – Blackjack

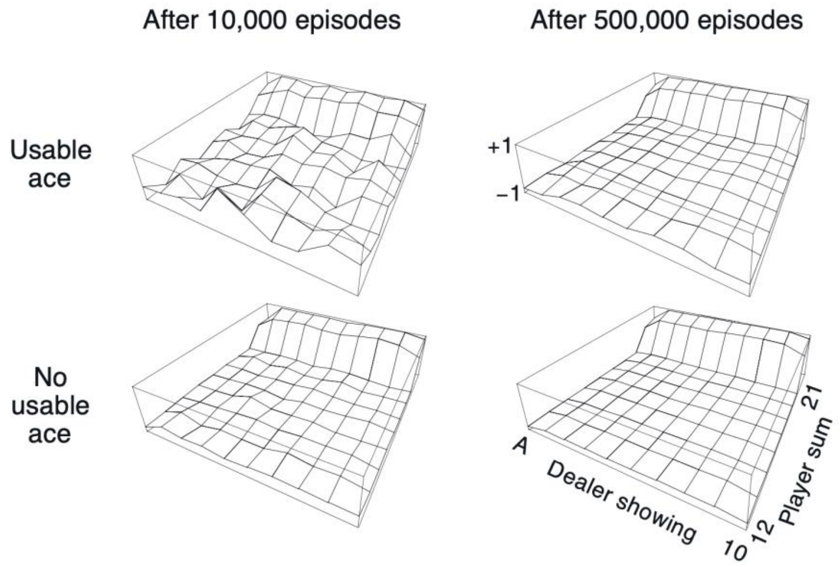


Figure 5.1: Approximate state-value functions for the blackjack policy that sticks only on 20 or 21, computed by Monte Carlo policy evaluation. ■

200 States:
- Player Hand 12 to 21
- Dealer Showing A to 10
- Player Ace / No Ace
- = 10x10x2

2 Actions:
- Hit or Stick

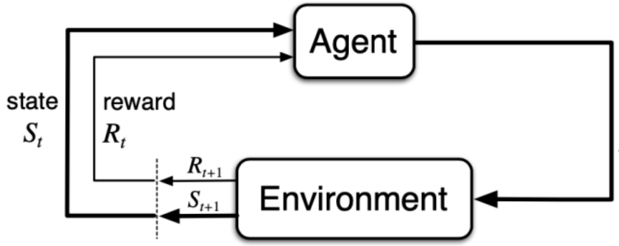
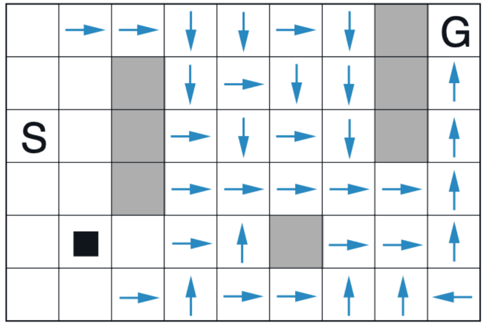


Figure 3.1: The agent–environment interaction in a Markov decision process.

Technical Overview - **Tabular Solution Methods**

Rich body of academic work spanning ~40 years

- Monte Carlo Methods
- TD Learning
- n-step Bootstrapping
- **Planning** and Learning
    - **Dyna**:
    - Monte Carlo Tree Search



Dyna – learns in real time

Technical Overview of RL

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Deep Learning

- DQN / Atari – Deep Learning
- AlphaZero – self play
- AlphaStar(craft)/ OpenAI Five - scale

Approximation Methods

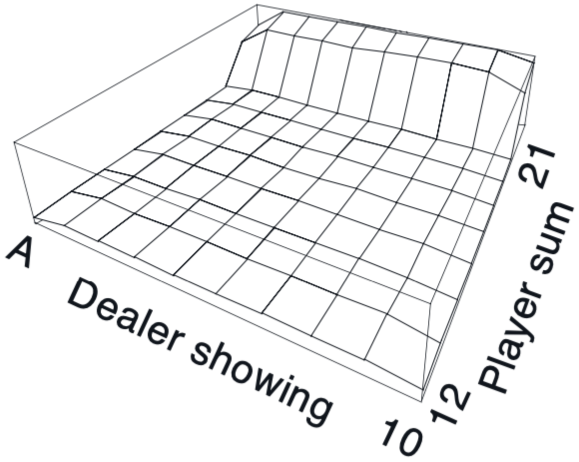
- Value Function Methods
- On-Policy vs Off-Policy
- Policy Gradient & Actor-Critic Methods
- Nonlinear Function Approximation

Tabular Methods

- Multi-arm bandits
- Dynamic Programming
- Markov Decision Process
- TD-Learning, Bootstrapping
- Planning

Technical Overview - **Approximation Methods**

How to deal with large state spaces:



$f(x)$

Why Tabular to Function Approximation?
#1 Intractability / memory
#2 Samples needed to fill large tables

Technical Overview - **Approximation Methods**

Rich body of academic work spanning ~40 years

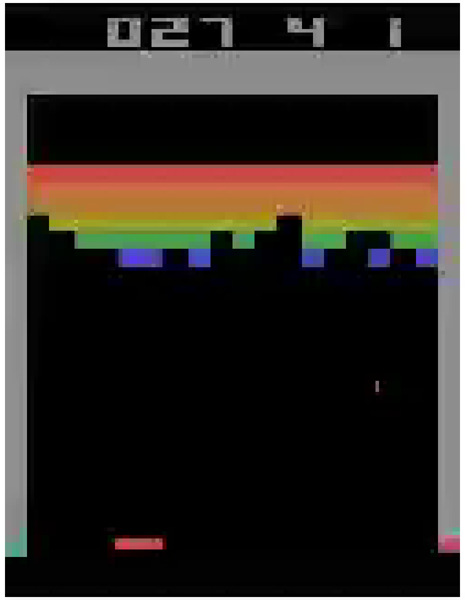
- Value Function Methods
- Policy Gradient Methods
- Actor-Critic Methods
- Nonlinear Function Approximation (Deep RL)

Technical Overview - **Approximation Methods**

Nonlinear Function Approximation – DQN Atari

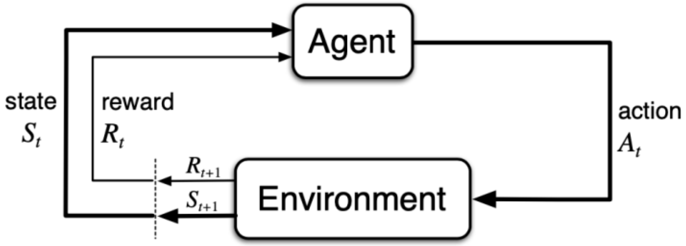
Network:
- 32 filters of 8 x 8, stride 4
- 64 filters of 4 x 4, stride 2
- 64 filters of 3 x 3, stride 1
- 512 fc
- 4 actions

Experience Replay:
- State, action, reward.
- Size = 1,000,000



States:
- 84 x 84 x 4 = 28,224

4 Actions:
- NoOp, Fire, Left, Right



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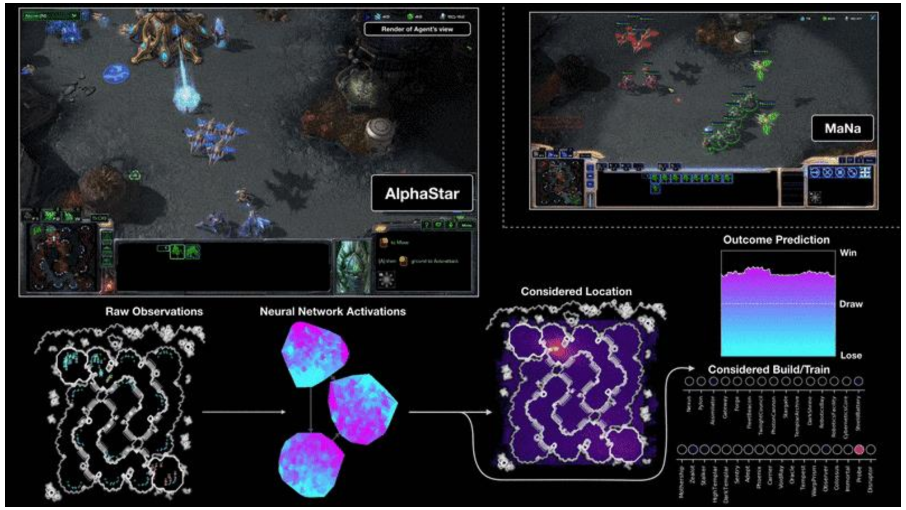
Technical Overview - **Approximation Methods**

Model Free

- OpenAI Five
- AlphaStar



Model Based

- AlphaZero

Technical Overview of RL

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- MuZero – planning without access to dynamics
- SuperDyna – approximation + partial observability + temporal abstraction + non-stationary

Deep Learning

- DQN / Atari – Deep Learning
- AlphaZero – self play
- AlphaStar(craft)/ OpenAI Five - scale

Approximation Methods

- Value Function Methods
- On-Policy vs Off-Policy
- Policy Gradient & Actor-Critic Methods
- Nonlinear Function Approximation

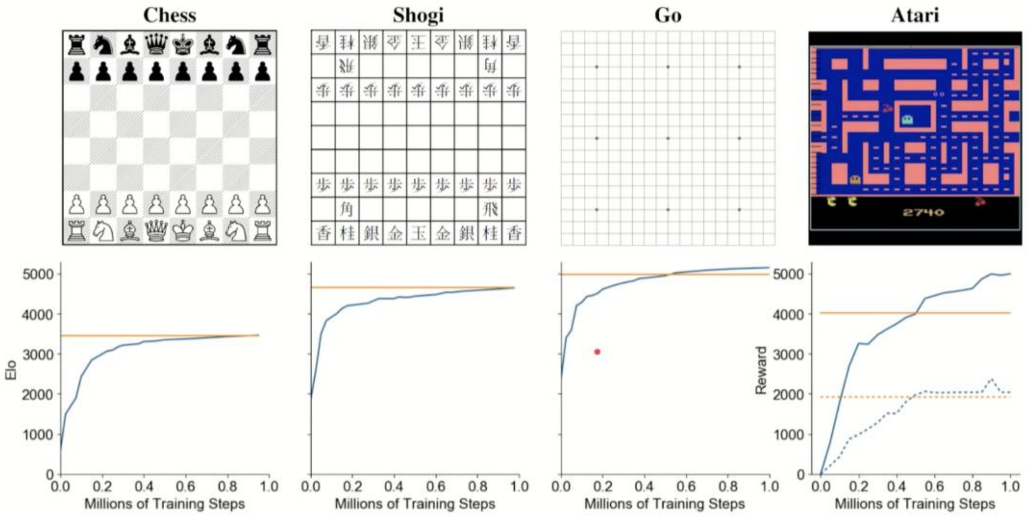
Tabular Methods

- Multi-arm bandits
- Dynamic Programming
- Markov Decision Process
- TD-Learning, Bootstrapping
- Planning

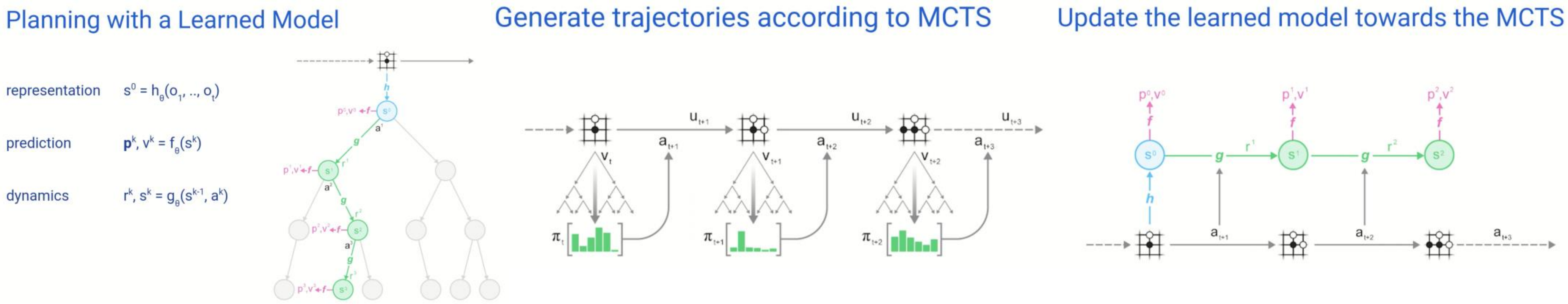
Technical Overview - **Approximation Methods**

Problem with Model Based

- We need the model – AlphaZero has the simulation of chess, Go, etc
- How could we do this for Atari?



Answer: MuZero, (Schrittwieser, et. El. 2019)



Technical Overview - **Approximation Methods**

Problem:

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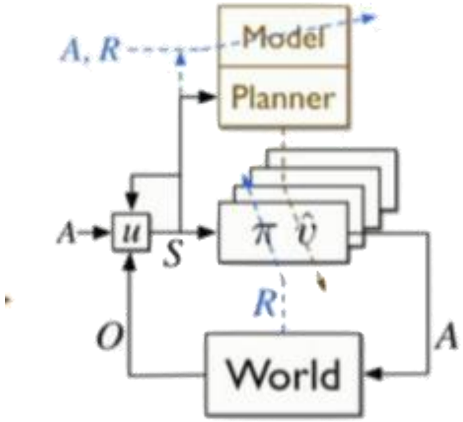
4k ROM vs A Google Data Center

Reality:

World is much bigger than Agent

Proposed solution: SuperDyna (working title) Rich Sutton 2019

- Learns subproblems, learns solutions (policies), learns state features, learns models of the world



How to Structure Problems to Use Reinforcement Learning Effectively

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Example RL Problem

Camera on Edge device:
  $$$ service
  (say person detection)

Goal: minimize cost
  don't request same person twice
  don't miss person

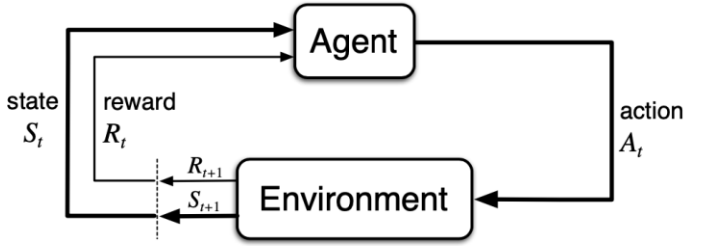


Figure 3.1: The agent–environment interaction in a Markov decision process.

Example RL Problem

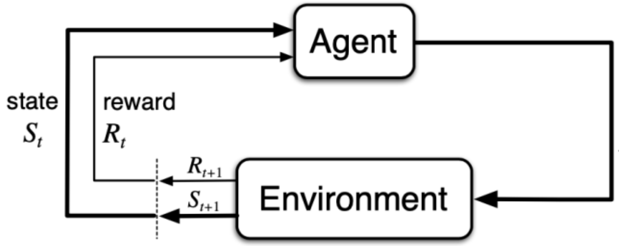
Camera on Edge device:
- $$$ service
- (say person detection)

Goal: minimize cost
- don’t request same person twice
- don’t miss person

States: 7,056 x n
- 84 x 84 x n
- n=number of history frames

2 Actions: **Skip**, **Send**

Reward:
- +1 new person,
- -0.1 same person, no one
- -1 missed person



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Example RL Problem

Camera on Edge device:
- $$$ service
- (say person detection)

Goal: minimize cost
- don't request same person twice
- don't miss person

States: 2 x n
- % change x n
- n=number of history frames
- + previous actions

2 Actions: **Skip**, **Send**

Reward:
- +1 new person,
- -0.1 same person, no one
- -1 missed person

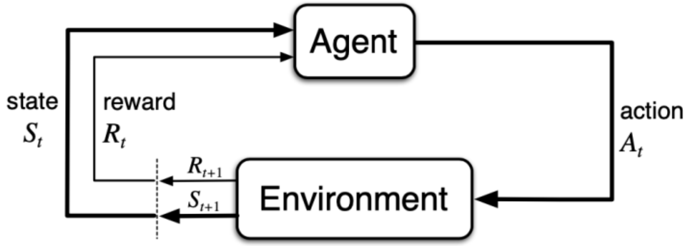

Figure 3.1: The agent–environment interaction in a Markov decision process.

Conclusions

Reinforcement Learning:

- A tool for exploring massive search spaces
- In use today
- Richly researched domain with continued innovation
- May be easier to use than you think

Resource Slide

Courses

Coursera: Reinforcement Learning Specialization (U. Alberta)

coursera.org/specializations/reinforcement-learning

Udacity: Deep Reinforcement Learning

udacity.com/course/deep-reinforcement-learning-nanodegree--nd893

OpenAI: Spinning Up (free)

spinningup.openai.com/en/latest/

Books

Reinforcement Learning (Sutton & Barto) (free)

incompleteideas.net/book/the-book-2nd.html

Contact Joe

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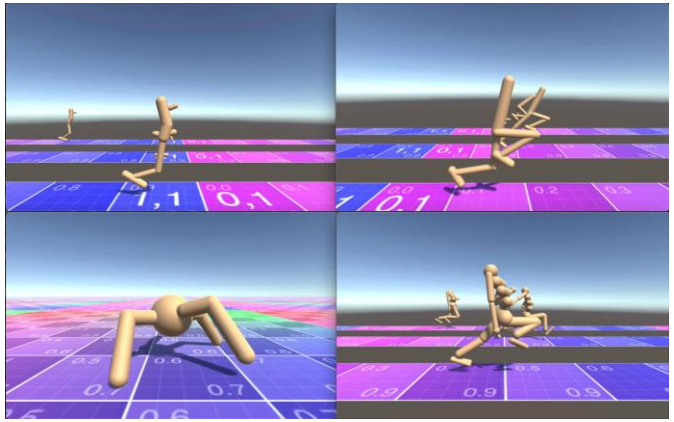
@iAmVidyaGamer



github.com/Unity-Technologies/marathon-envs