Introduction to Reinforcement Learning

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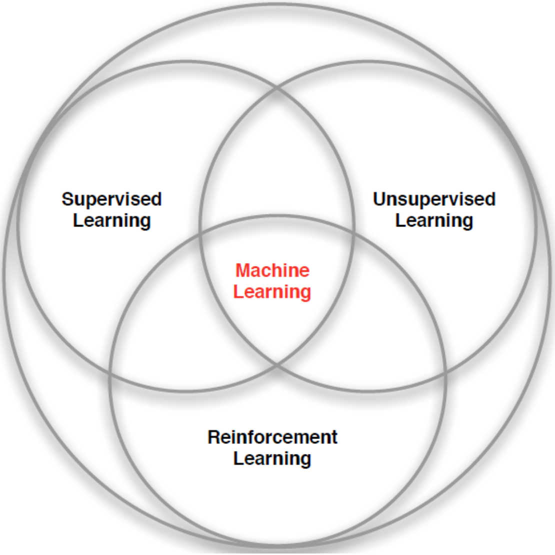
June 21, 2019

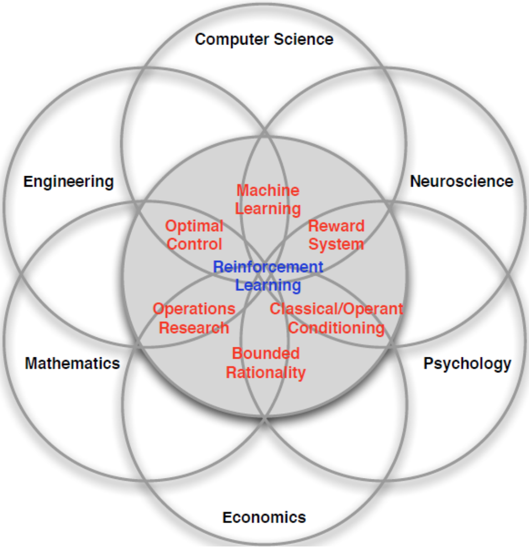
Overview

1. Why RL?
2. What is RL?
3. Components
4. Examples
5. Resources

Branches of Machine Learning



Domains of Reinforcement Learning



Examples of Reinforcement Learning

- Performing stunts on an helicopter[1].
- Managing an investment portfolio.
- Playing atari games better than humans[2].
- Defeating world champion of Go[3].
- Performing drug discovery[4].

[1] Abbeel, et al. "An application of reinforcement learning to aerobatic helicopter flight." in *NIPS 2007*.

[2] Mnih, et al. "Human-level control through deep reinforcement learning." in *Nature 2015*.

[3] Silver, et al. "Mastering the game of Go with deep neural networks and tree search." in *Nature 2016*.

[4] AlphaFold 2018. Available at `https://deepmind.com/blog/alphafold/`

Autonomous Helicopter Flight[1]

[1] Abbeel, et al. “An application of reinforcement learning to aerobatic helicopter flight.” in *NIPS 2007*.

Characteristics of Reinforcement Learning

What makes Reinforcement Learning different?

- There is no supervision, only a *reward* signal.
- Feedback is delayed, not instantaneous.
- Agent's actions effect subsequent data it receives.

Reward Hypothesis

Reinforcement learning is based on the *reward hypothesis*:

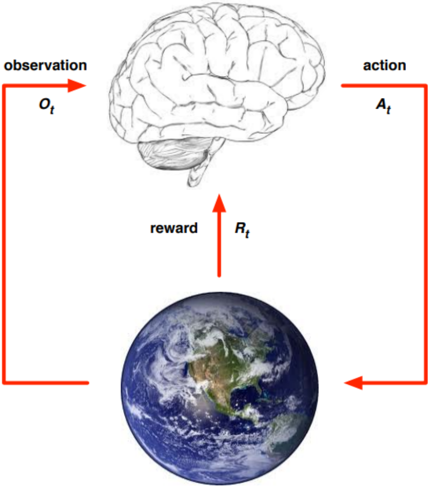
Reward Hypothesis

All goals can be described by maximization of expected cumulative reward.

Example of rewards:

- Helicopter Flight:
  - Reward for following desired trajectory.
  - Punishment for crashing.
- Play Atari games:
  - Reward/punishment for increasing/decreasing score.

Agent and Environment



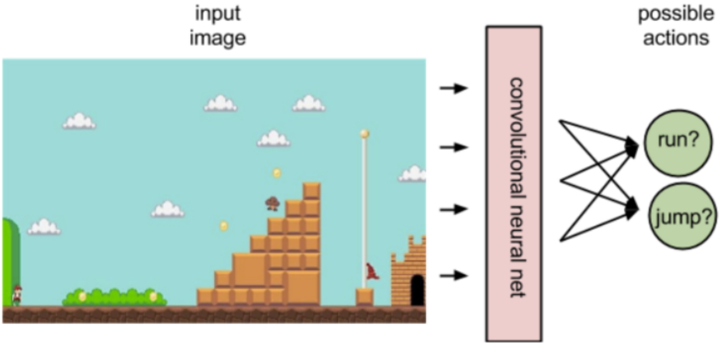
- At each step t, the agent:
    - Executes action a_t.
    - Receives states s_t.
    - Receives scalar reward r_t.
- The environment:
    - Receives action a_t.
    - Emits observation s_{t+1}.
    - Emits scalar reward r_{t+1}.

Major Components of RL Agents

- RL Agent may include following components:
  - Policy: Agent's behavior function.
  - Value function: Utility of each state and/or action.
  - Model: Agent's representation of the environment.

Policy

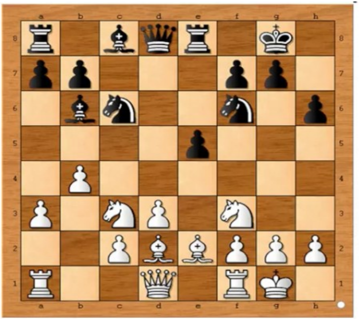
- A *policy* models the agent's behavior.
- Function from state to action.
- Deterministic policy: $a = \pi(s)$.
- Stochastic policy: $\pi(a|s) = \mathbb{P}[a_t = a|s_t = s]$.



Value Function

- Value function is a prediction of future reward.
- Used to evaluate the goodness/badness of states.
- Select between actions using this value function.

$$v_\pi(s) = \mathbb{E}_\pi[r_{t+1} + \gamma r_{t+2} + \gamma^2 r_{t+3} + \cdots | s_t = s]$$



Is this a good state for white?

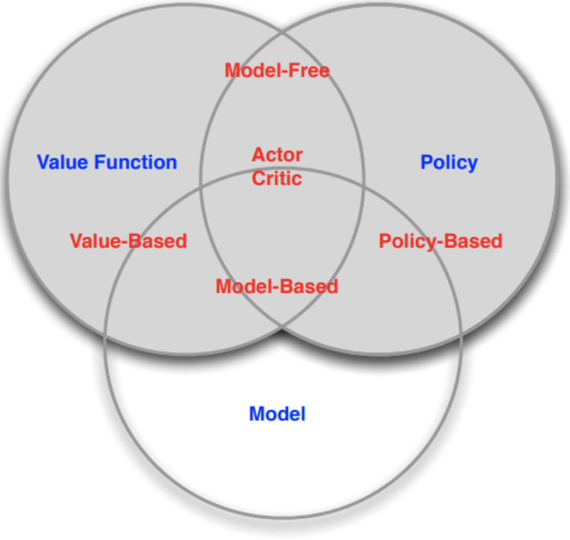
Model

- A *model* predicts what the environment will do next
- $\mathcal{P}$ predicts the next state
- $\mathcal{R}$ predicts the next reward

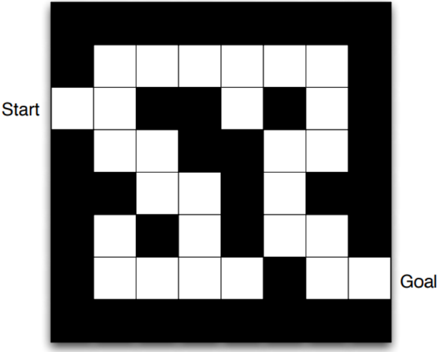
$$\mathcal{P}^{a}_{ss'} = \mathbb{P}[s_{t+1} = s' | s_t = s, a_t = a]$$

$$\mathcal{R}^{a}_{s} = \mathbb{R}[r_{t+1} | s_t = s, a_t = a]$$

Taxonomy of RL Algorithms

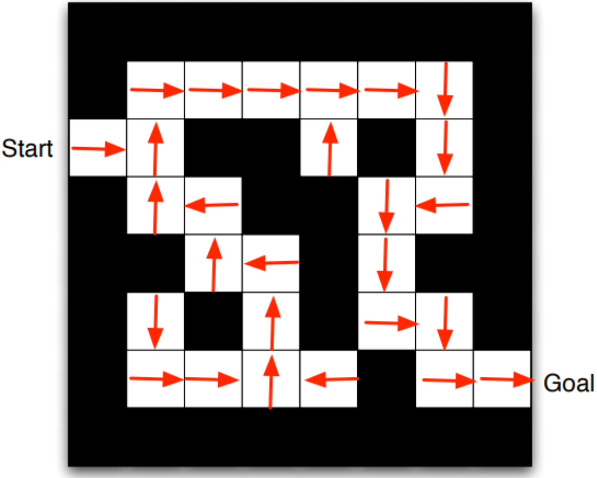


Maze Example



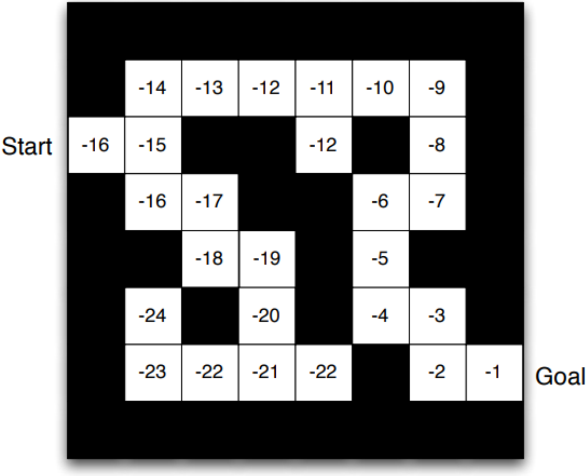
- Rewards: -1 per time step.
- Actions: N,S,E,W.
- State: Agent's position on maze.

Maze Example: Policy



Red arrows indicate actions taken as per policy.

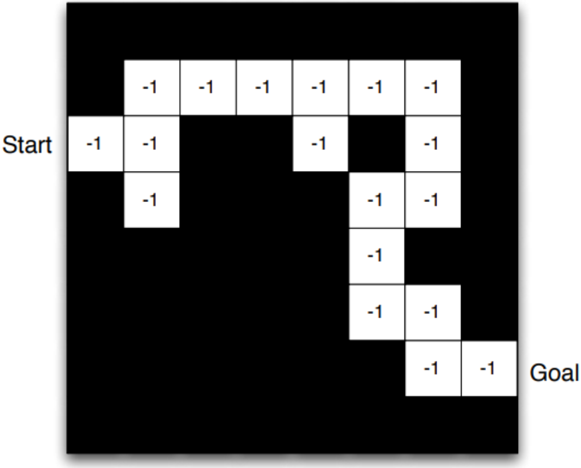
Maze Example: Value Function



		-14	-13	-12	-11	-10	-9		
Start	-16	-15			-12		-8		
		-16	-17			-6	-7		
			-18	-19		-5			
		-24		-20		-4	-3		
		-23	-22	-21	-22		-2	-1	Goal

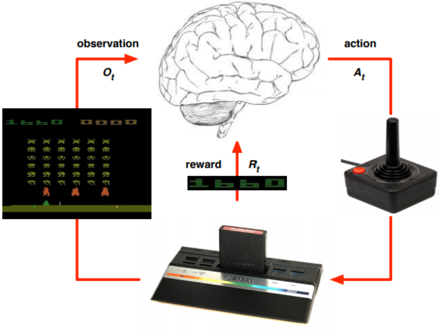
Numbers in grid indicate expected *long-term* rewards for that cell.

Maze Example: Model



$\mathcal{P}^a_{ss'}$ and $\mathcal{R}^a_s$ are shown by grid and numbers.
Note: Model can be imperfect!

Case Study: Atari Game Play



- Learn directly from interactive game play.
- Relies on value function based RL.
- Approximate value function using deep neural network.

[1] Mnih, et al. “Human-level control through deep reinforcement learning.” in *Nature 2015*.

Tutorials for RL

- Andrew Ng: CS 229 Course Lectures 16-20[1].
- David Silver: Reinforcement Learning Course[2].
- Spinning up with Deep Reinforcement Learning: OpenAI[3].

[1] https://www.youtube.com/watch?v=UzxYlbK2c7E

[2] http://www0.cs.ucl.ac.uk/staff/d.silver/web/Teaching.html

[3] https://spinningup.openai.com/en/latest/

Software Resources

- Awesome Reinforcement Learning: github.com/aikorea/awesome-rl.

- OpenAI Gym: `github.com/openai/gym`.
- Unity ML: `github.com/Unity-Technologies/ml-agents`.

- garage: `github.com/rlworkgroup/garage`.
- trfl: `github.com/deepmind/trfl/`.

Thank You