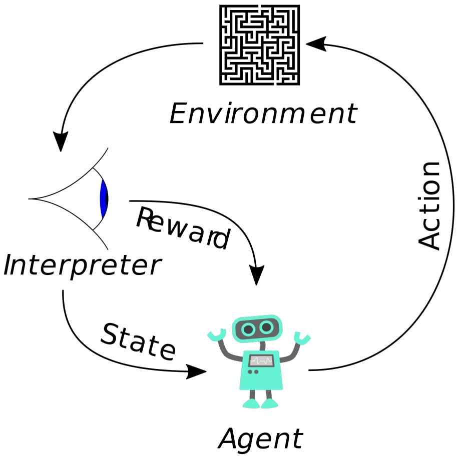
Chapter 1: Introduction

Seungjae Ryan Lee

Reinforcement Learning

- Learning by interacting with the environment
- Goal: maximize a numerical reward signal by choosing correct actions
  - **Trial and error**: learner is not told the best action
  - **Delayed rewards**: actions can affect all future rewards



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vs. Supervised and Unsupervised Learning

- No external supervisor / teacher
  - No training set with labeled examples (answers)
  - Need to interact with environment in uncharted territories
- Different goals
  - Supervised Learning: Generalize existing data to minimize test set error
  - Reinforcement Learning: Maximize reward through interactions
  - Unsupervised Learning: Find hidden structure

→ Reinforcement Learning is a new paradigm of Machine Learning

Characteristics of Reinforcement Learning

- Interactions between agent and environment
- Uncertainty about the environment
  - Effects of actions cannot be fully predicted
  - Monitor environment and react appropriately
- Defined goal
  - Judge progress through rewards
- Present affects the future
  - Effect can be delayed
- Experience improves performance

Example: Preparing Breakfast

- Complex sequence of interactions to achieve goal

Get cereal → Get bowl → Get spoon → Get milk → Pour cereal → Pour milk → Grab spoon

- Need to observe and react to the uncertainty of the environment
  - Grab different bowl if current bowl is dirty
  - Stop pouring if the bowl is about to overflow
- Actions have delayed consequences
  - Failing to get spoon does not matter until you start eating
- Experience improves performance

Exploration vs Exploitation

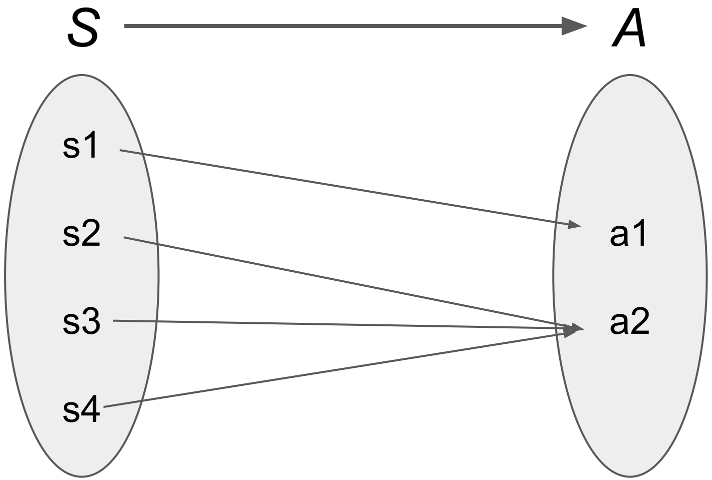
- **Exploration**: Try different actions
- **Exploitation**: Choose best known action
- Need both to obtain high reward

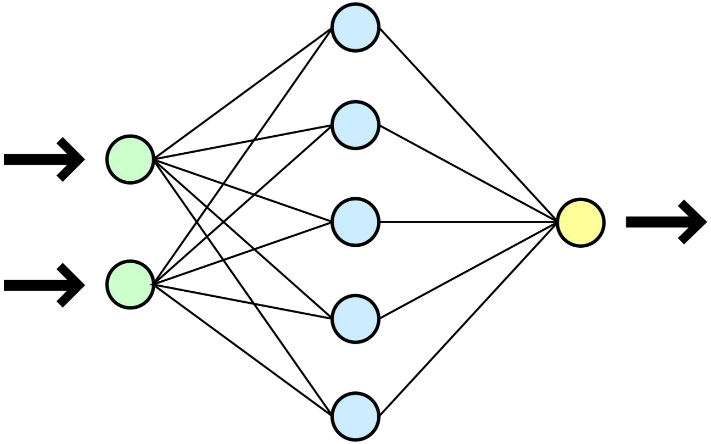
Elements of Reinforcement Learning

- **Policy** defines the agent’s behavior
- **Reward Signal** defines the goal of the problem
- **Value Function** indicates the long-term desirability of state
- **Model** of the environment mimics behavior of environment

Policy

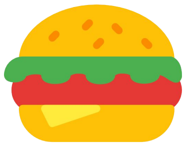
- Mapping from *observation* to *action*
- Defines the agent's behavior
- Can be stochastic

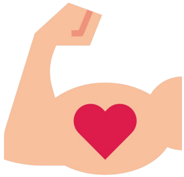




Reward Signal vs. Value Function

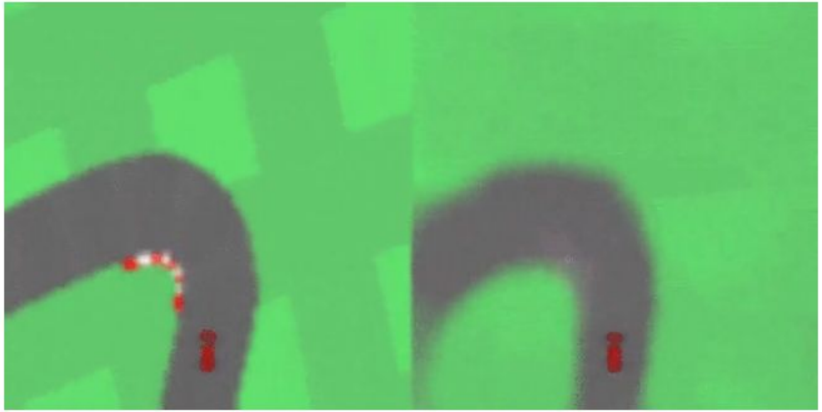
- Reward
  - Immediate reward of action
  - Defines good/bad events for the agent
  - Given by the environment
- Value Function
  - Sum of future rewards from a state
  - Long-term desirability of states
  - Difficult to estimate
  - **Primary basis of choosing action**





Model

- Mimics the behavior of environment
- Allow *planning* a future course of actions
- Not necessary for all RL methods
  - *Model-based* methods use the model for planning
  - *Model-free* methods only use trial-and-error



Actual observations from the environment. What gets encoded into z_t.

https://worldmodels.github.io/

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Example: Tic Tac Toe

- Assume **imperfect opponent**
- Agent needs to find and exploit imperfections

Tic Tac Toe with Reinforcement Learning

- Initialize value functions to 0.5 (except terminal states)
- Learn by playing games
  - Move *greedily* most times, but *explore* sometimes
- Incrementally update value functions by playing games
- Decrease learning rate over time to converge

$$V(s) \leftarrow V(s) + \alpha[V(s') - V(s)]$$

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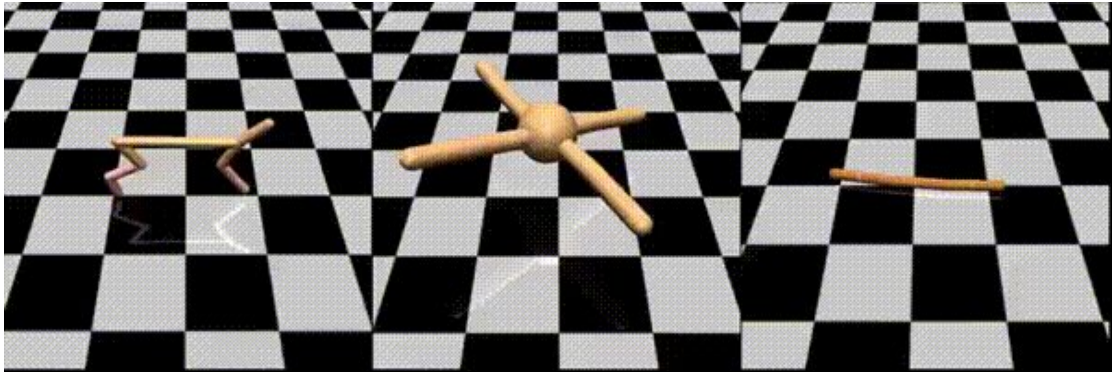
Tic Tac Toe with other algorithms

- Minimax algorithm
  - Assumes best play for opponent → Cannot exploit opponent
- Classic optimization
  - Require complete specification of opponent → Impractical
  - ex. Dynamic Programming
- Evolutionary methods
  - Finds optimal algorithm
  - Ignores useful structure of RL problems
  - Works best when good policy can be found easily

Reinforcement Learning beyond Tic-Tac-Toe

- Can be applied to:
  - more complex games (ex. Backgammon)
  - problems without enemies (“games against nature”)
  - problems with partially observable environments
  - non-episodic problems
  - continuous-time problems



https://blog.openai.com/evolution-strategies/

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Thank you!

Original content from

- Reinforcement Learning: An Introduction by Sutton and Barto

You can find more content in

- github.com/seungjaeryanlee
- www.endtoend.ai