Reinforcement Learning Fundamentals

Lecture 5: Multi-armed Bandit

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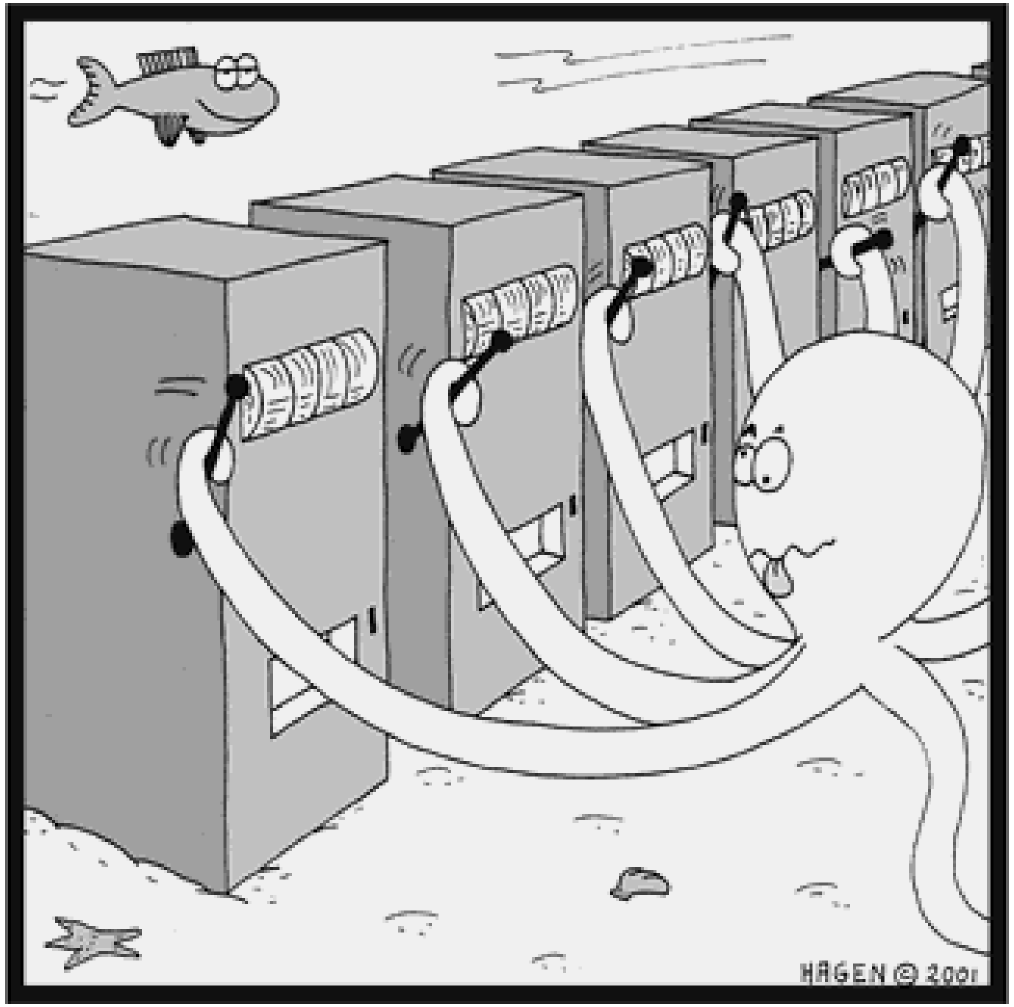
In today's class…

- Immediate RL Problems
- Exploration vs. Exploitation
- Multi-armed Bandit
- ϵ-greedy algorithms
- Performance metrics



Immediate RL Problems

- Every time instant **t**, pick an action $\mathbf{a_t}$ and get a reward $\mathbf{R_t}$.

- There is no state!

- Example:
    - Testing a drug for effectiveness
    - Tossing a coin

- 3 Actions: Choose one of the 3 coins

Coin 1

$\mathbb{P}\{\text{heads}\} = p_1$

Coin 2

$\mathbb{P}\{\text{heads}\} = p_2$

Coin 3

$\mathbb{P}\{\text{heads}\} = p_3$

Given 10 trials at tossing, maximize the total number of heads.

If, the probabilities p1, p2, and p3 are given, then?

How many heads in 10 tosses?

Exploration and Exploitation

- Reinforcement learning is like trial-and-error learning
- The agent should discover a good policy
  - From its experiences of the environment
  - Without losing too much reward along the way

  - **Exploration** finds more information about the environment
  - **Exploitation** exploits known information to maximize reward
  - It is usually important to explore as well as exploit

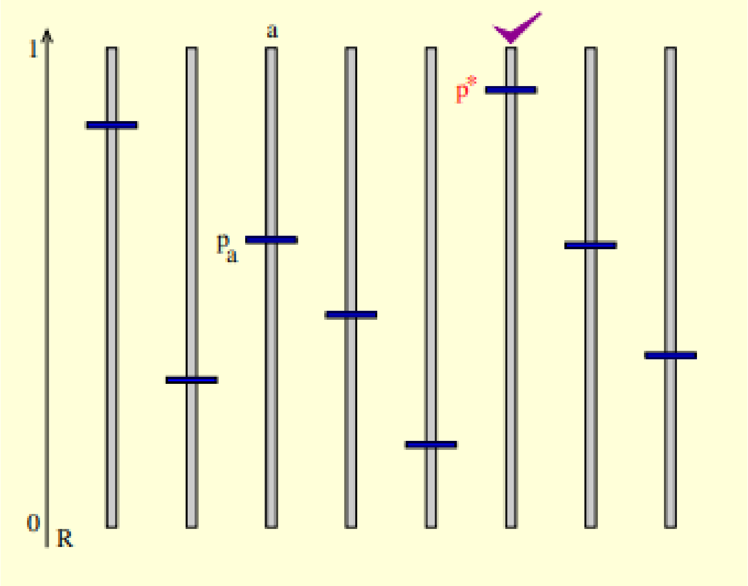
Exploration vs. Exploitation

Examples?
What is exploration and exploitation in these examples?

- Restaurant Selection
- Online Advertising: Template optimization
- Clinical trials
- Packet routing in communication networks
- Game playing and reinforcement learning
- Oil Drilling or Mining

Multi-armed Bandit

- A hypothetical experiment where a person must **choose between multiple actions** (i.e., slot machines, the "one-armed bandits"), **each with an unknown payout**.



- The goal is to determine the best or **most profitable outcome** through a series of choices.

- At the beginning of the experiment, when odds and payouts are unknown, the gambler must determine **which machine to pull, in which order and how many times**.

Algorithm to solve Multi-armed Bandit?

- Here is what an algorithm does—

  For $t = 0, 1, 2, \ldots, T - 1$:

  - Given the history $h_t = (a_0, r_0, a_1, r_1, a_2, r_2, \ldots, a_{t-1}, r_{t-1})$,
  - Pick an arm a_t to sample (or "pull"), and
  - Obtain a reward r_t drawn from the distribution corresponding to arm a_t.
- T is the total sampling budget, or the horizon.
- Formally: a deterministic algorithm is a mapping

  from the set of all histories

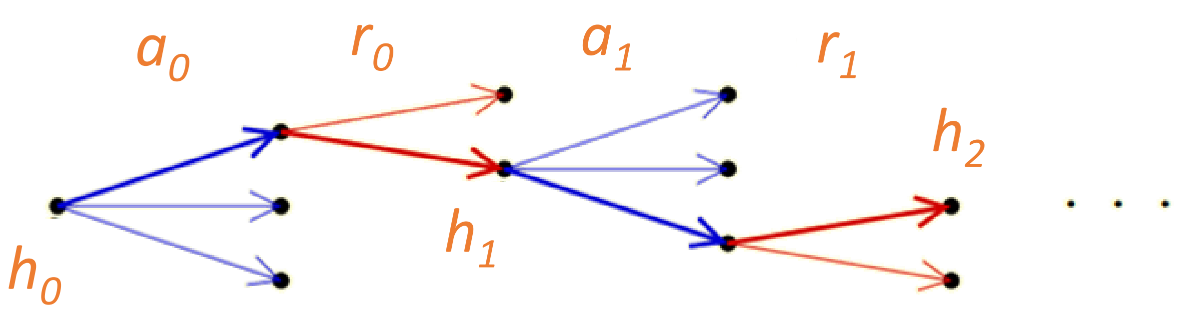
  to the set of all arms.
- Formally: a **stochastic** algorithm is a mapping

  from the set of all histories

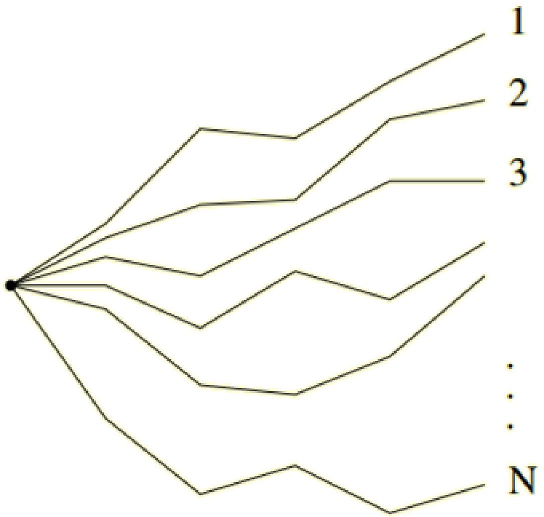
  to the set of all probability distributions over arms.
- The algorithm picks the arm to pull; the bandit instance returns the reward.

Slide from Prof. Shivaram Kalyanakrishnan's course: "Foundations of Intelligent and Learning Agents."

Multi-armed Bandit Tree



- An algorithm, bandit instance pair can generate many possible T-length histories.



For a complete horizon T,

$h_T = (a_0, r_0, a_1, r_1, a_2, r_2, \ldots, a_{T-1}, r_{T-1}),$

$P(h_t) = \prod_{t=0}^{t=T} \underbrace{P(a_t \mid ht)}_{\text{Decided by the Algorithm}} \underbrace{P(r_t \mid a_t)}_{\text{Decided by the bandit instance}}$

How many histories possible if the algorithm is deterministic and rewards 0–1?

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