

Exploration and Exploitation (Bandits)

Last Time

- What is Reinforcement Learning?
- What are the main challenges in Reinforcement Learning?
- How do we categorize RL approaches?

Last Time

First RL Algorithm:

Tabular Maximum Likelihood Model-Based Reinforcement Learning

loop

choose action a

gain experience

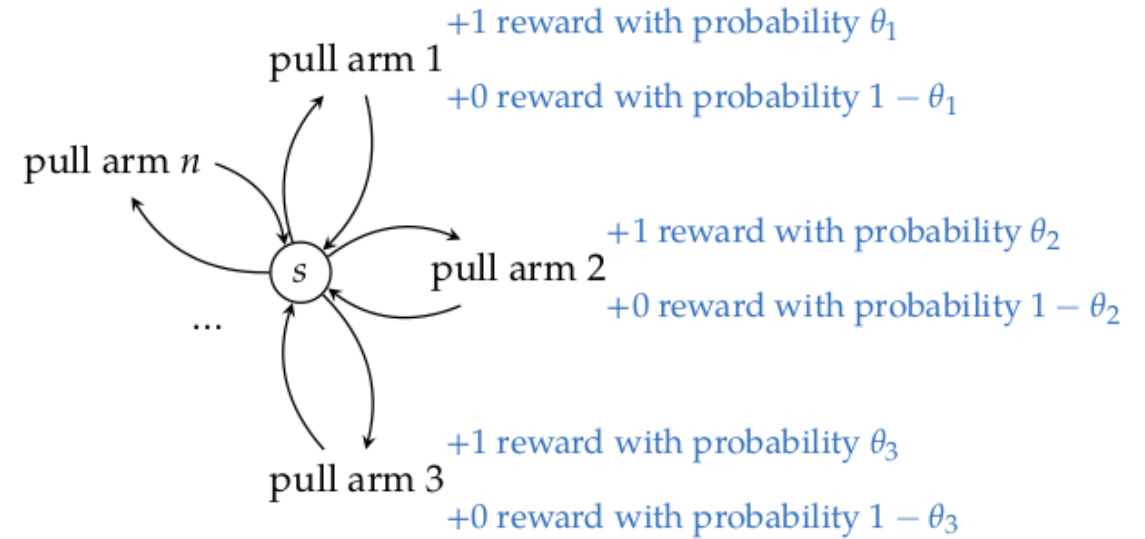
estimate T, R

solve MDP with T, R

Guiding Questions

- What are the best ways to trade off Exploration and Exploitation?

Bandits



- Bernoulli Bandit with parameters θ
- $\theta^* \equiv \max \theta$

“According to Peter Whittle, “efforts to solve [bandit problems] so sapped the energies and minds of Allied analysts that the suggestion was made that the problem be dropped over Germany as the ultimate instrument of intellectual sabotage.”

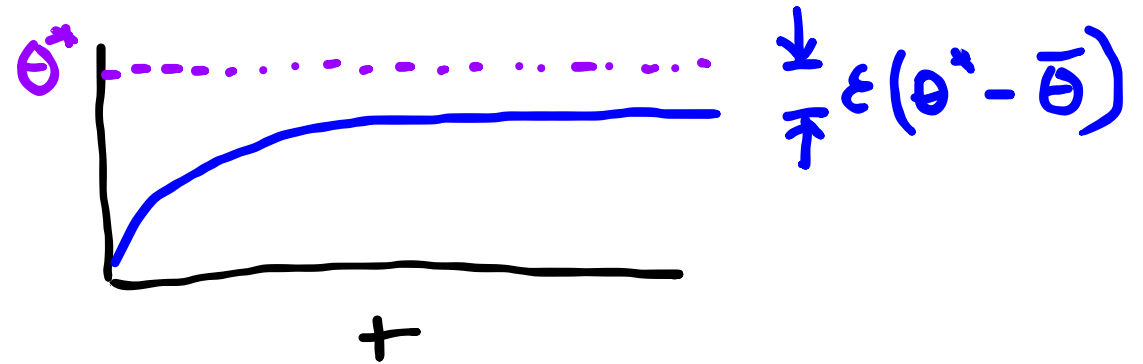
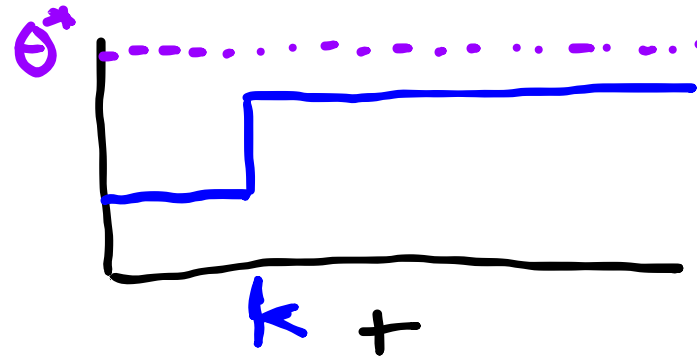
Greedy Strategy

$$\rho_a = \frac{\text{number of wins} + 1}{\text{number of tries} + 1}$$

Choose $\operatorname{argmax}_a \rho_a$

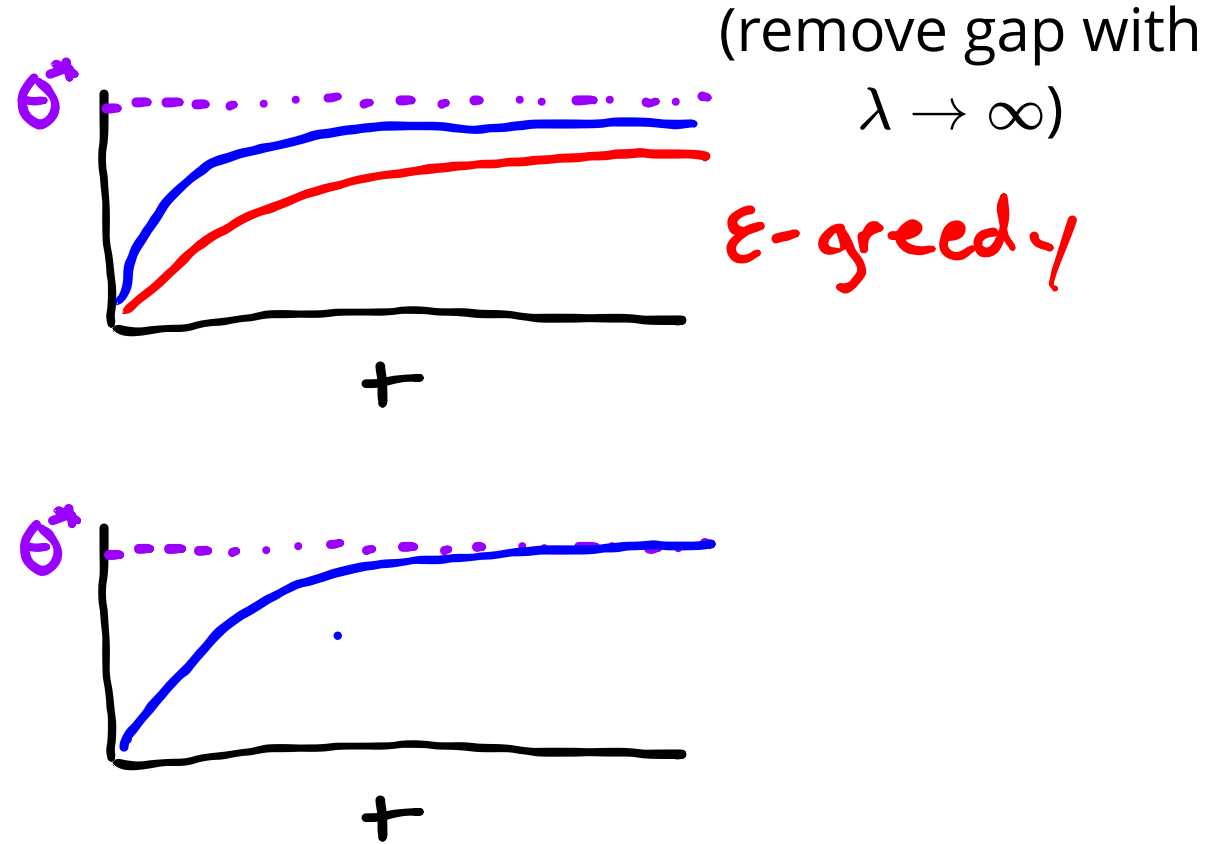
Undirected Strategies

- Explore then Commit
Choose a randomly for k steps
Then choose $\arg\max_a \rho_a$
- ϵ - greedy
With probability ϵ , choose randomly
Otherwise choose $\arg\max_a \rho_a$



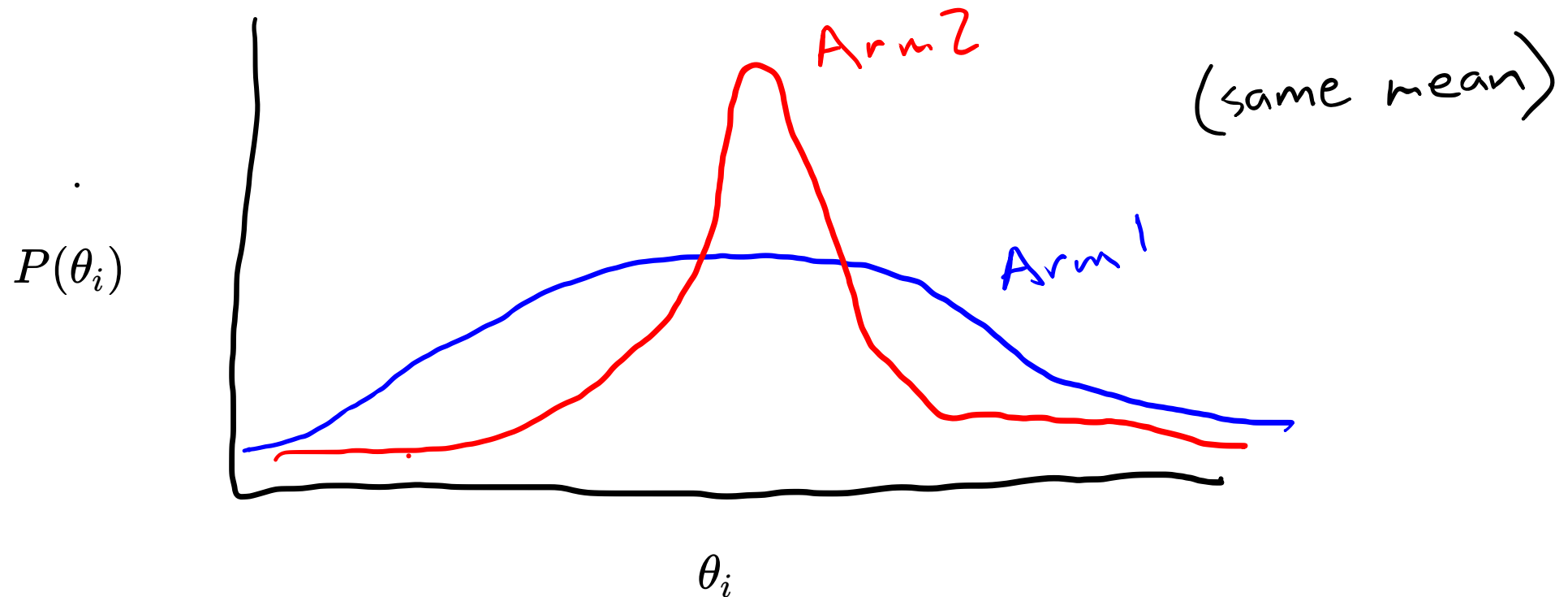
Directed Strategies

- Softmax
Choose a with probability
proportional to $e^{\lambda \rho_a}$
- Upper Confidence Bound (UCB)
Choose $\operatorname{argmax}_a \rho_a + c \sqrt{\frac{\log N}{N(a)}}$



Break

Discuss with your neighbor: Suppose you have the following *belief* about the parameters θ . Which arm should you choose to pull next?

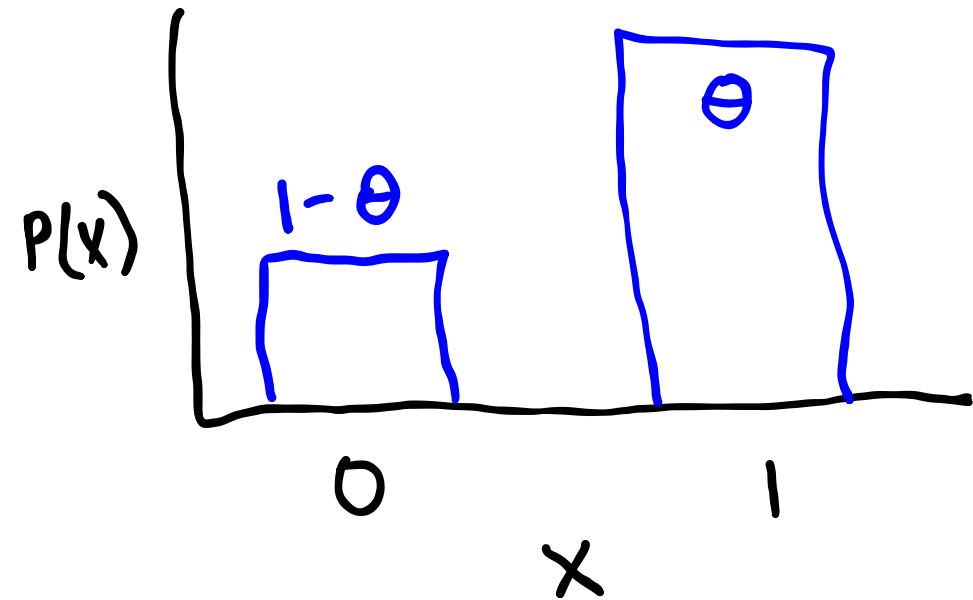


Bayesian Estimation

Bernoulli Distribution

Bernoulli(θ)

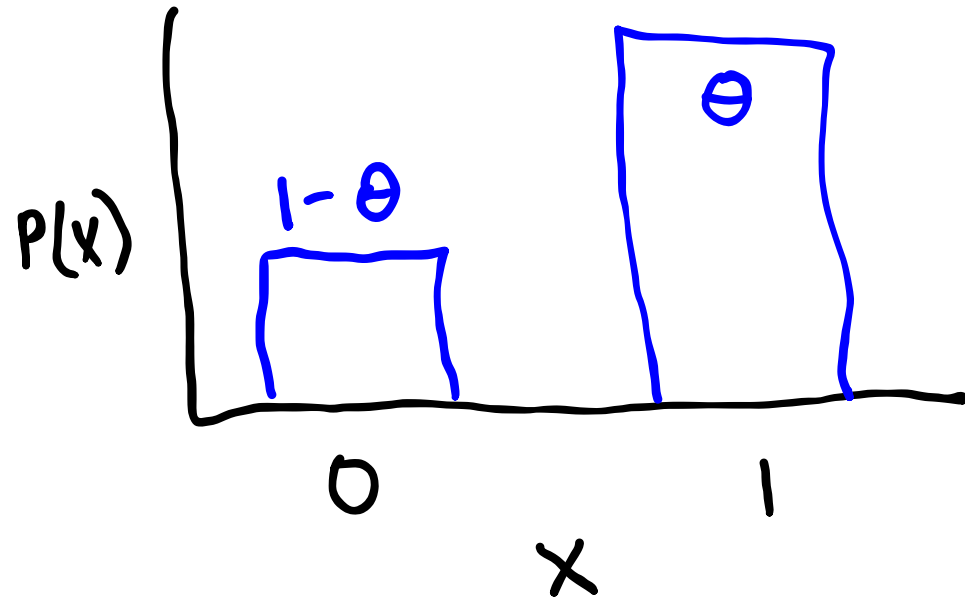
Discussion: Given that I have received w wins and l losses, what should my belief (probability distribution) about θ look like?



Bayesian Estimation

Bernoulli Distribution

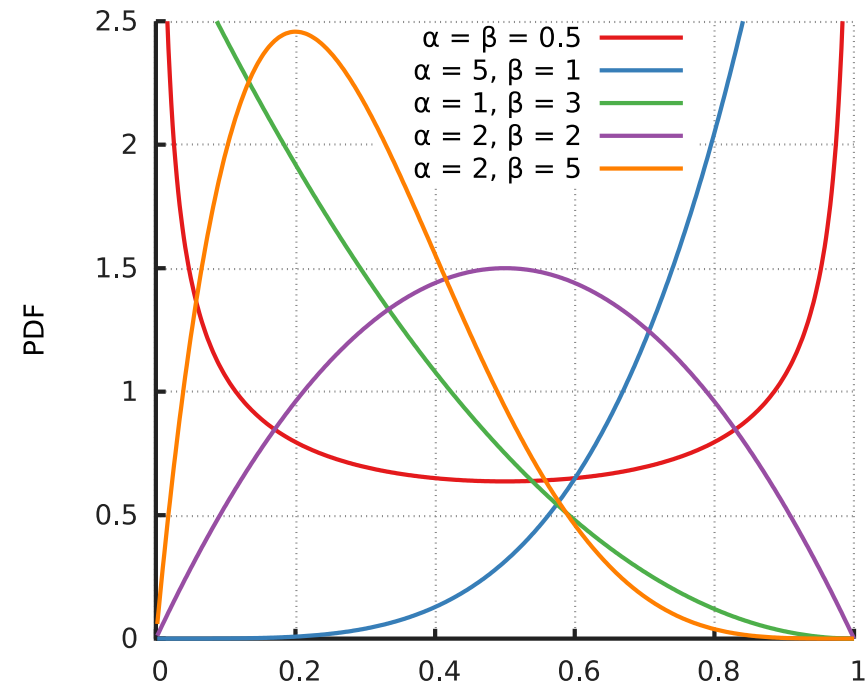
$\text{Bernoulli}(\theta)$



Beta Distribution

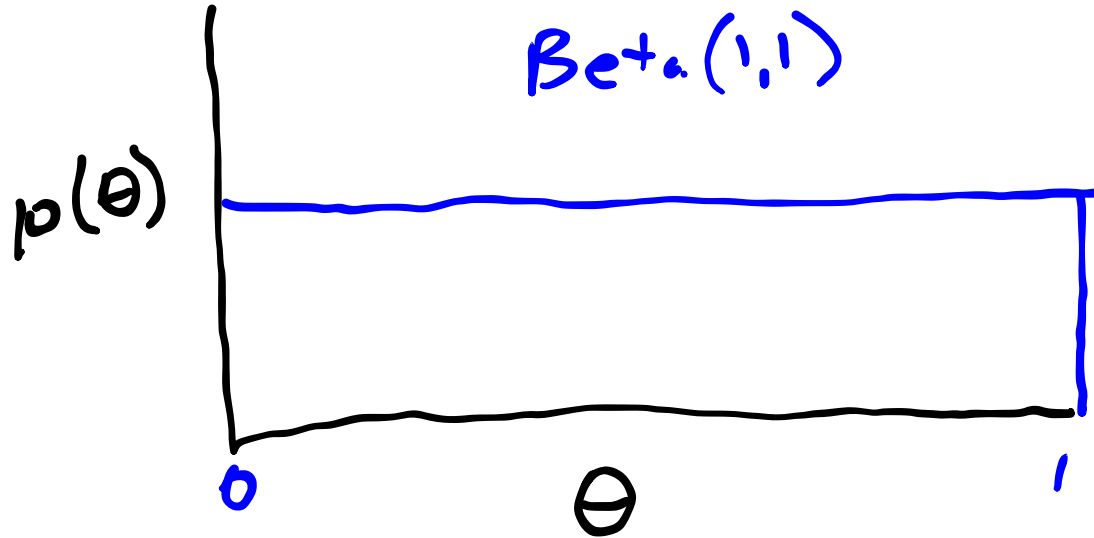
(distribution over Bernoulli distributions)

$\text{Beta}(\alpha, \beta)$

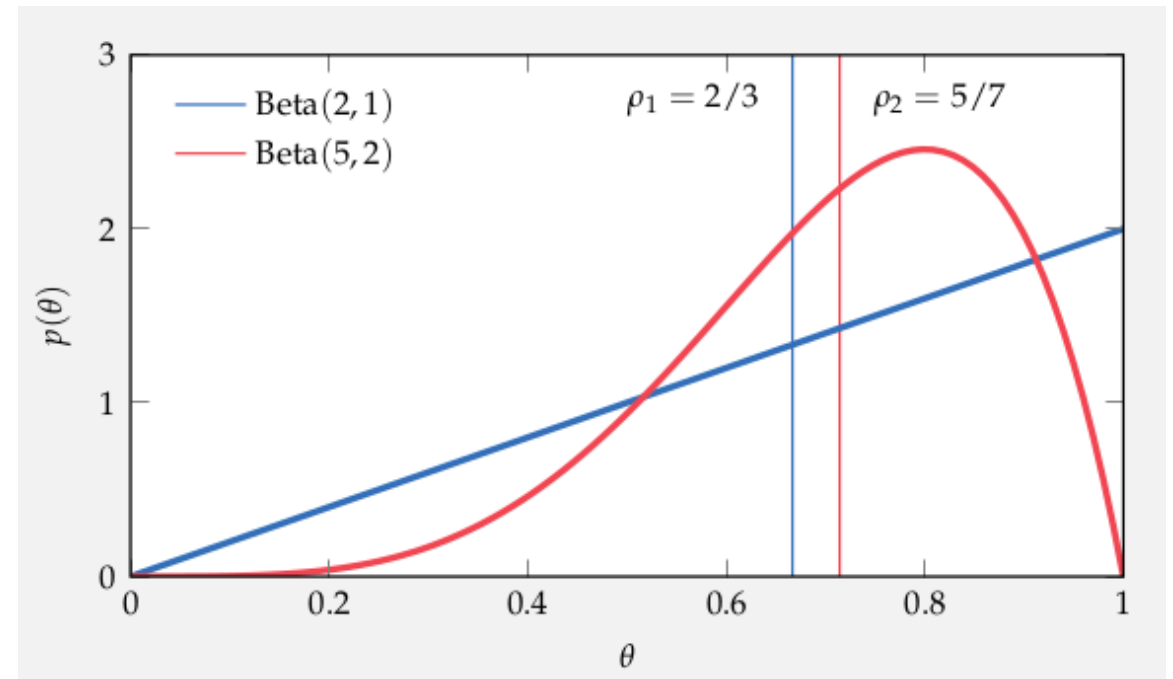


Bayesian Estimation

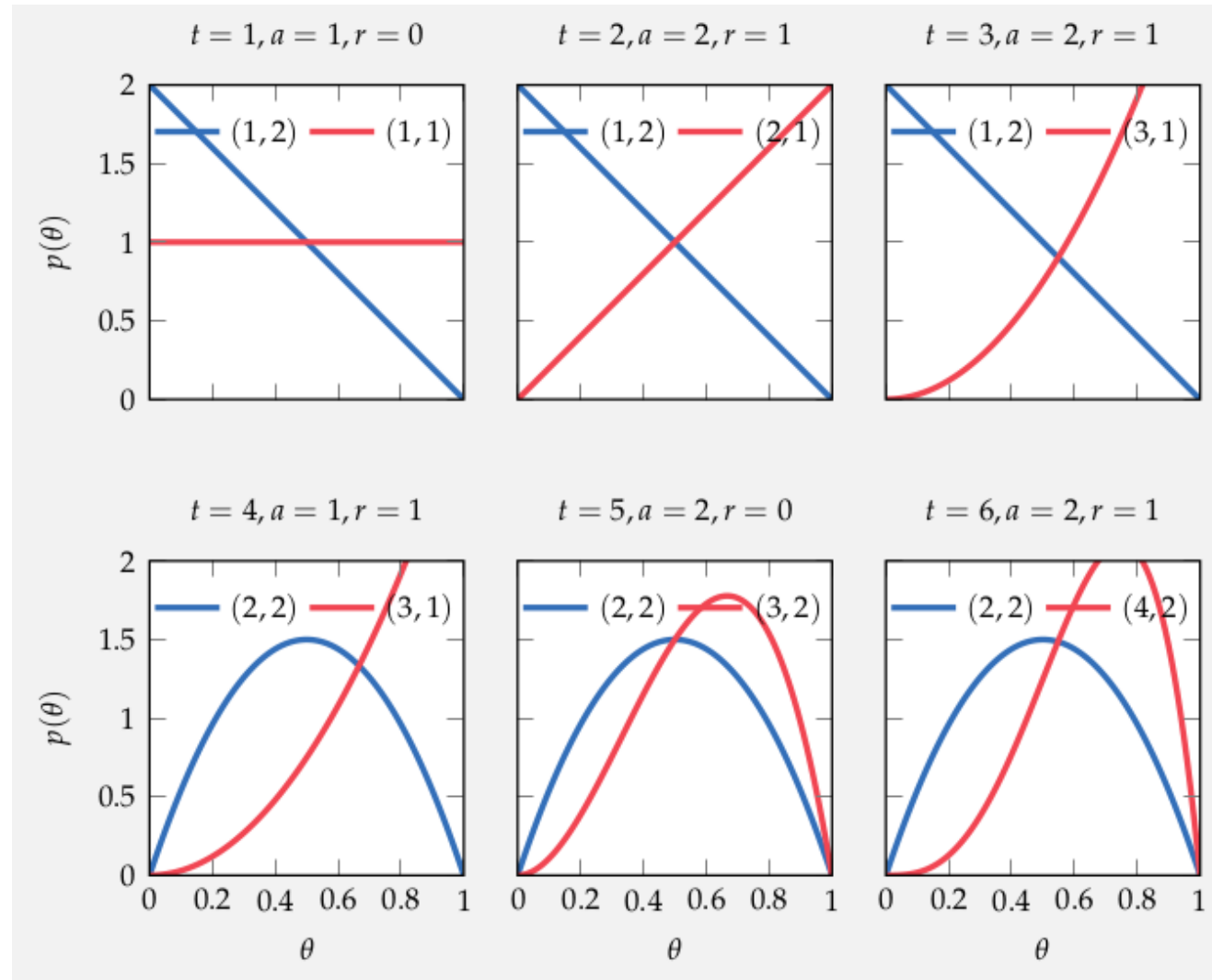
Given a Beta(1, 1) prior distribution



The posterior distribution of θ is
Beta($w + 1, l + 1$)



Bayesian Estimation



t = time

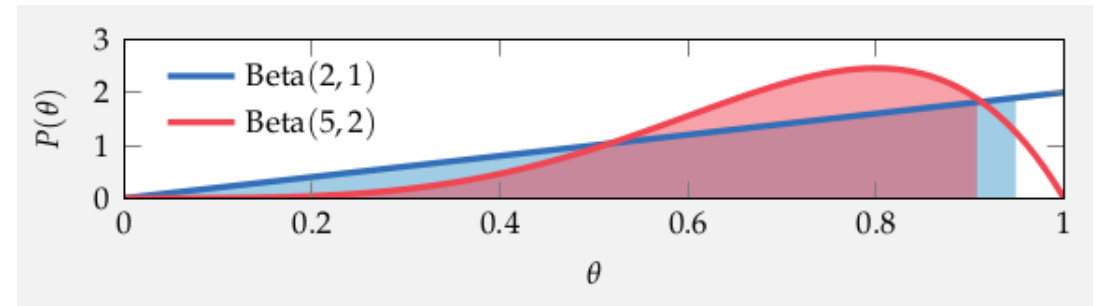
a = arm pulled

r = reward

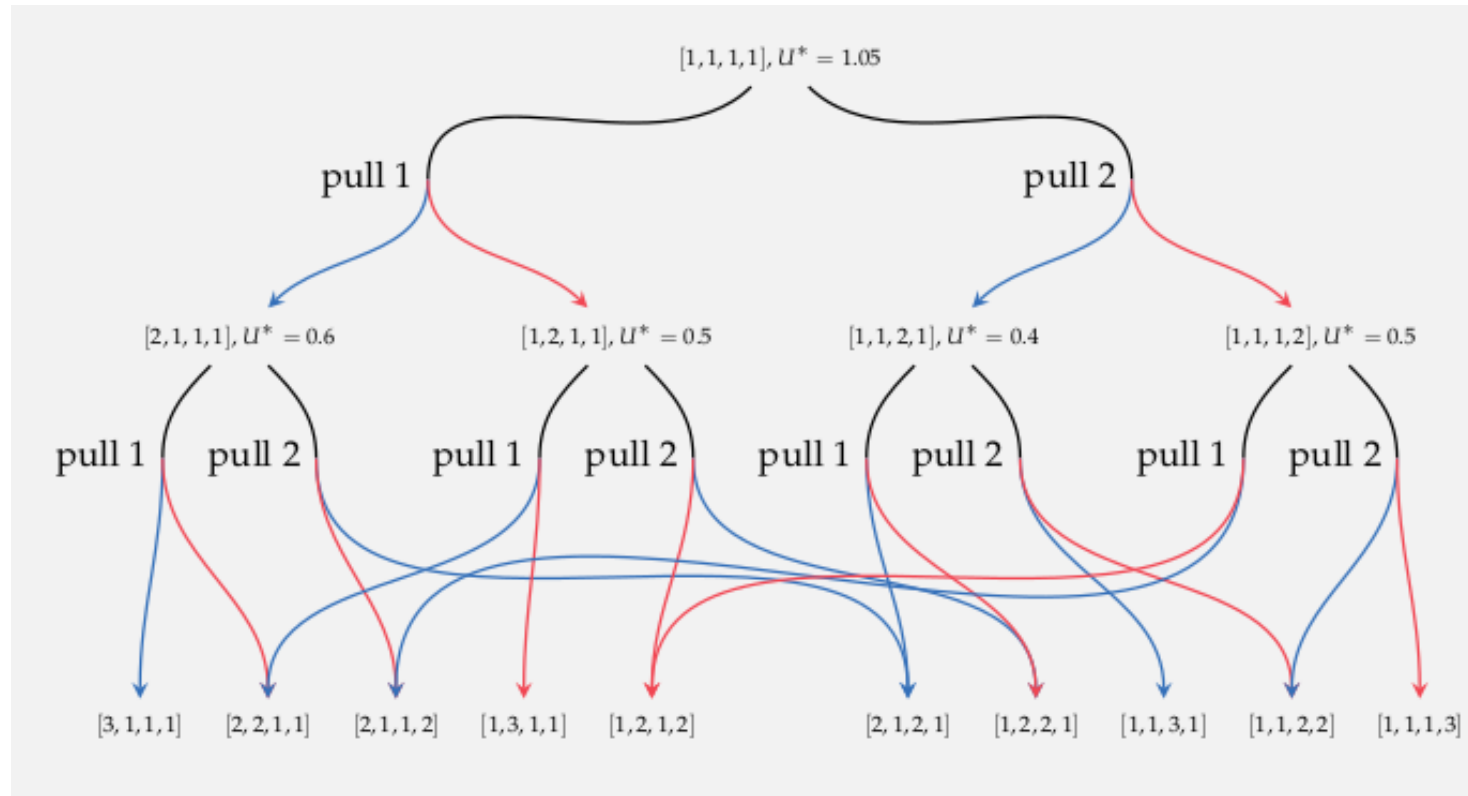
Bayesian Bandit Algorithms

$$\alpha = 0.9$$

- Quantile Selection
Choose a for which the α quantile of $b(\theta)$ is highest
- Thompson Sampling
Sample $\hat{\theta}$
Choose $\operatorname{argmax}_a \hat{\theta}_a$



Optimal Algorithm - Dynamic Programming



Review

Guiding Questions

- What are the best ways to trade off Exploration and Exploitation