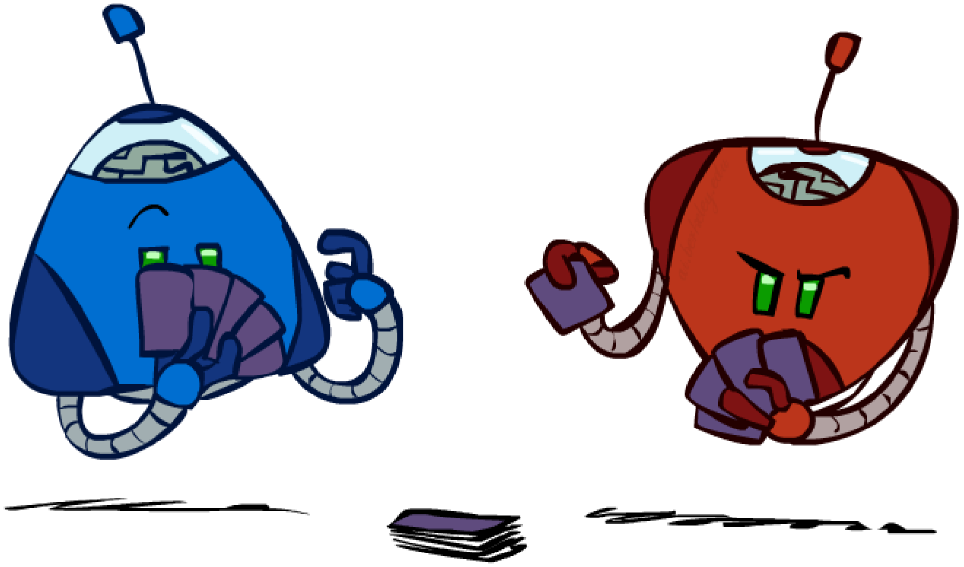
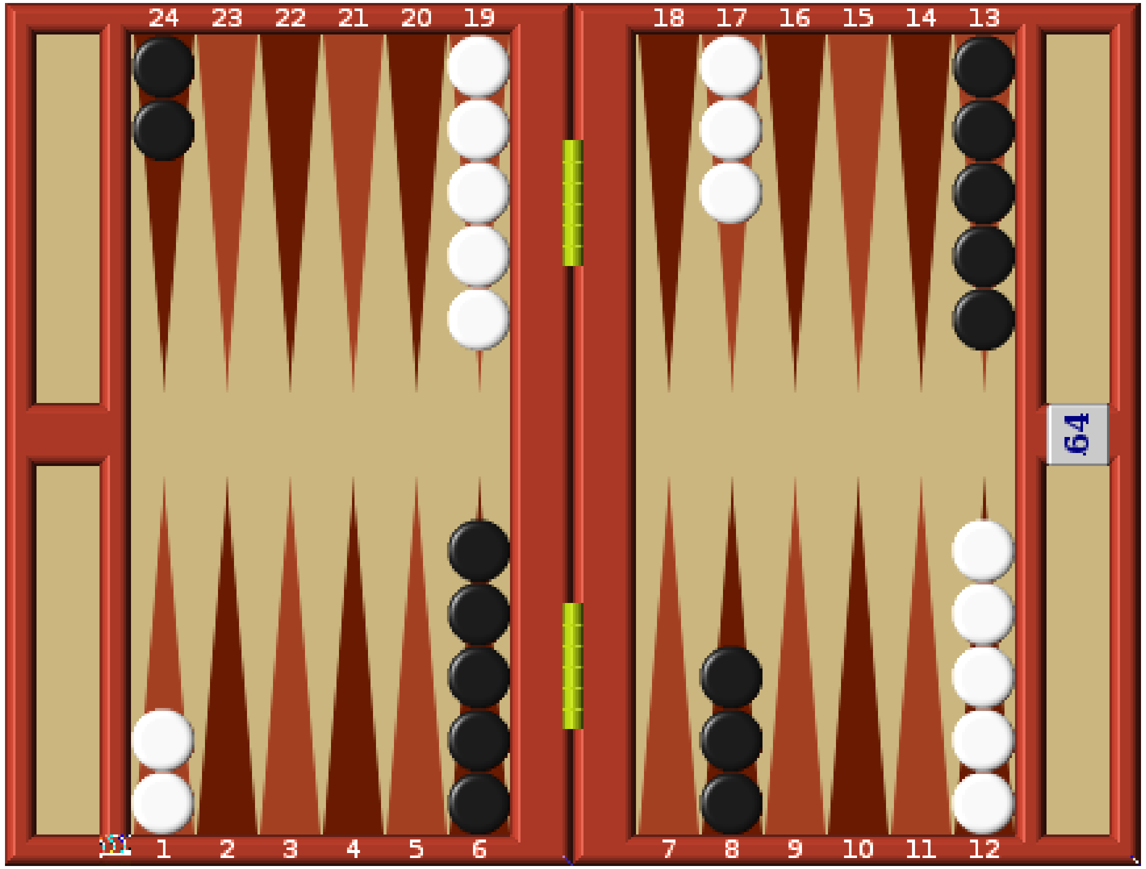
Stochastic Search



[These slides were created by Dan Klein and Pieter Abbeel for CS188 Intro to AI at UC Berkeley. All CS188 materials are available at http://ai.berkeley.edu.]

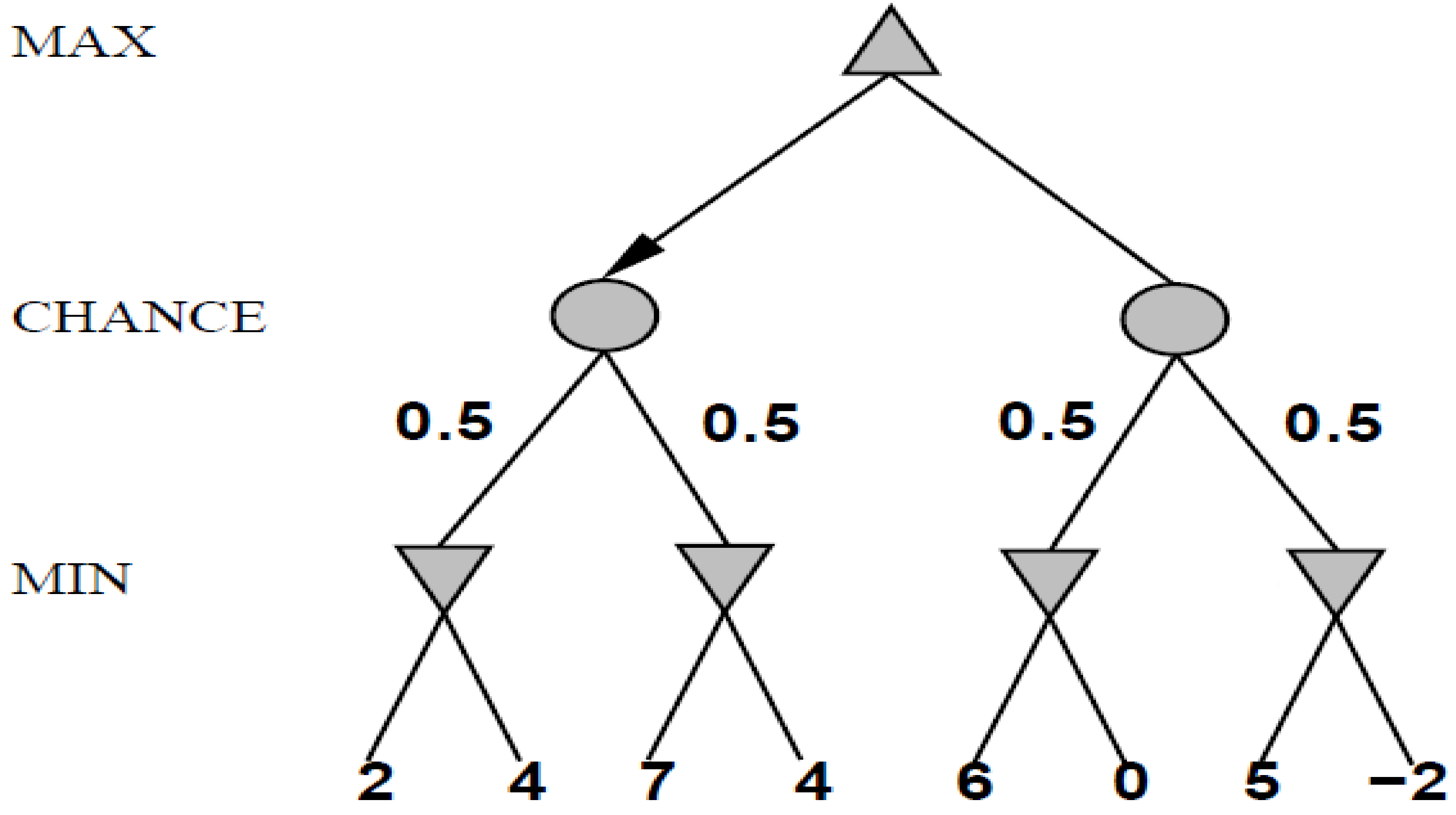
Nondeterministic Games

- In nondeterministic games, chance introduced by dice, card-shuffling



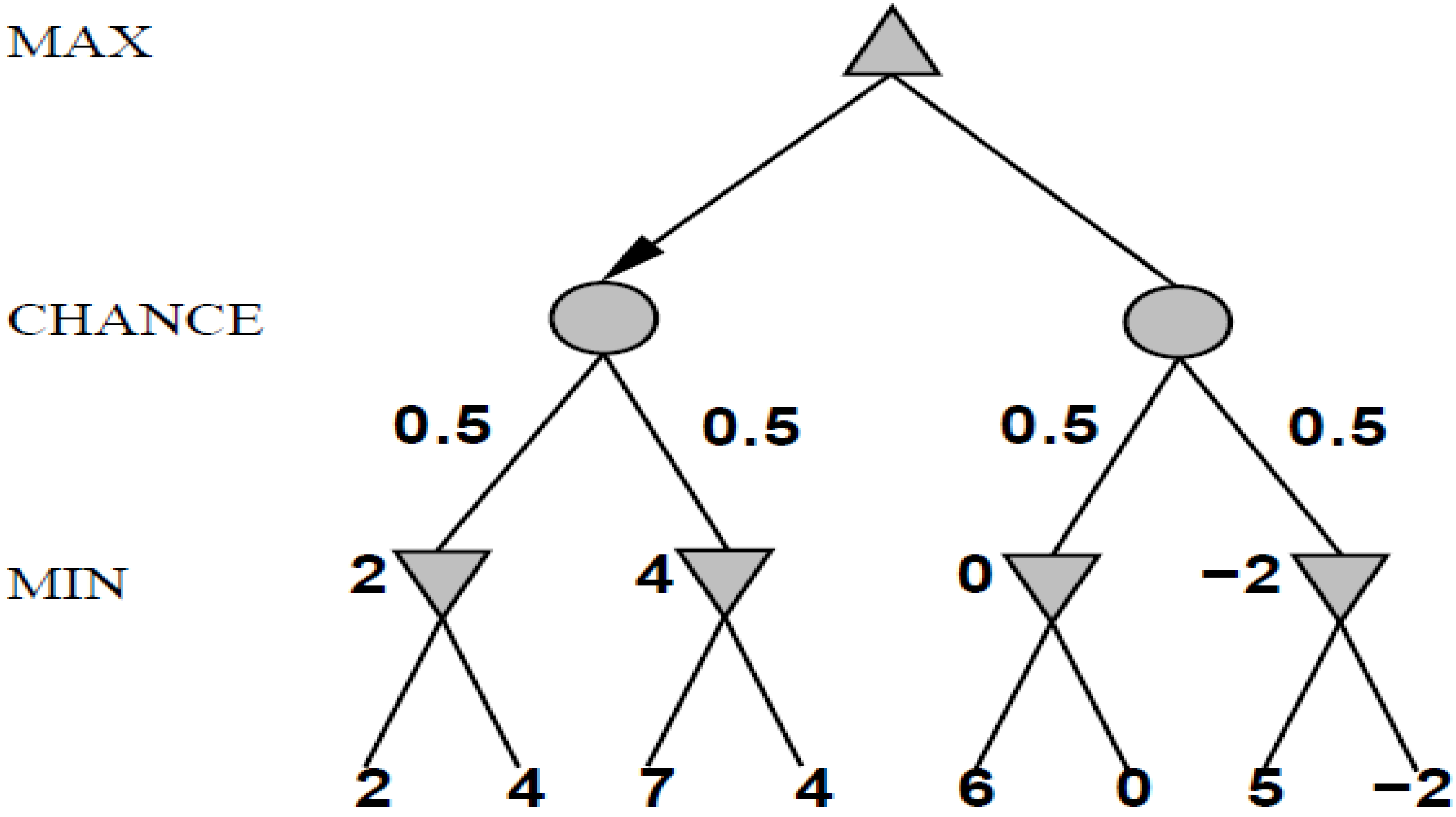
Nondeterministic Games in General

- Simplified example with coin-flipping:
  - Minimax tree with chance nodes added



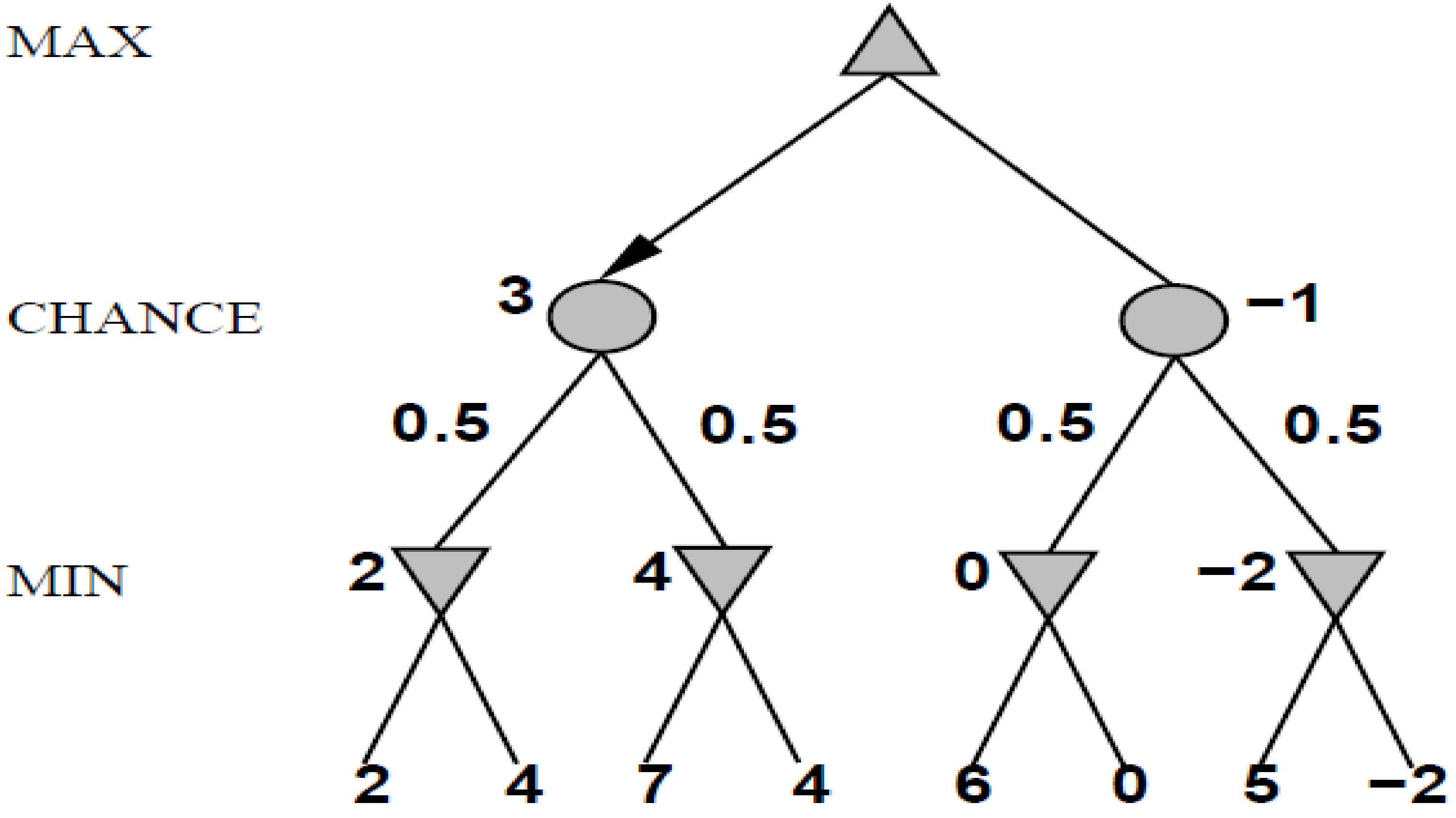
Nondeterministic Games in General

- Simplified example with coin-flipping:
  - Min makes choices just like we'd expect



Nondeterministic Games in General

- Simplified example with coin-flipping:
  - We use probability to calculate the expected value of each choice at the chance nodes



Algorithm for Nondeterministic Games

- Expectiminimax is just like Minimax, except we must also handle chance nodes:

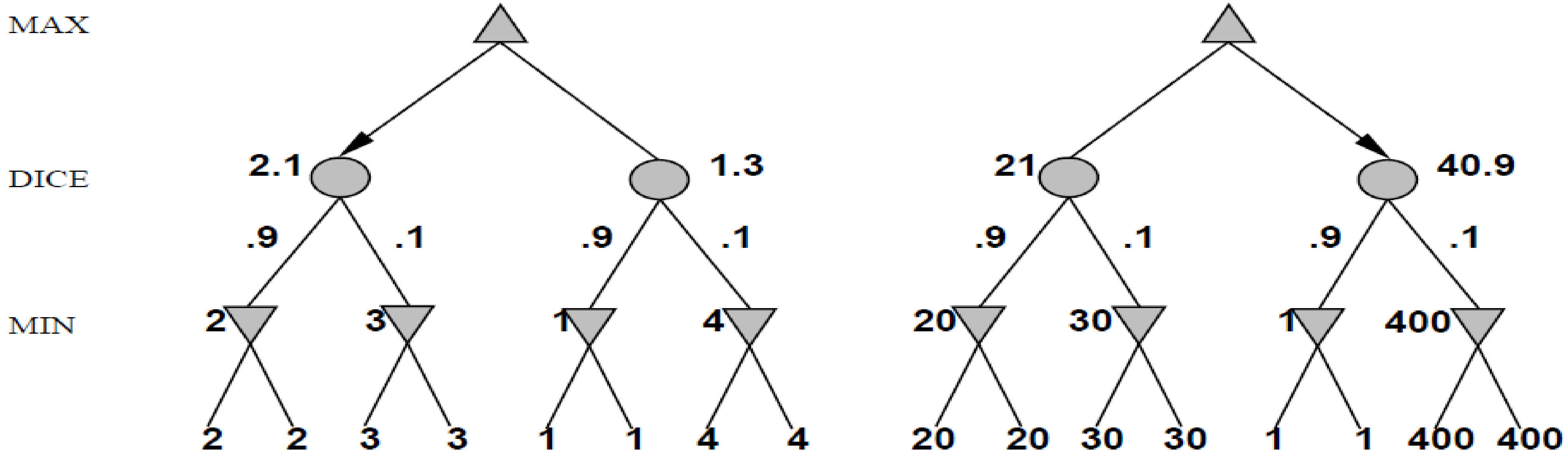
```
...
if state is a MAX node then
        return the highest EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
if state is a MIN node then
        return the lowest EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
if state is a chance node then
        return average of EXPECTIMINIMAX-VALUE of SUCCESSORS(state)
...
```

Nondeterministic Games in Practice

- Dice rolls increase branching factor: 21 possible rolls with 2 dice
- Backgammon ~ 20 legal moves
  - Depth 4 = $20 \times (21 \times 20)^3 \sim 1.2 \times 10^9$
- As depth increases, probability of reaching a given node shrinks
  - Value of lookahead is seriously diminished
- α-β pruning is much less effective
- TDGammon uses depth-2 search + very good Eval
  - World-champion level

Exact Values DO Matter

- Behavior is preserved only by positive linear transformation of Eval
- Hence Eval should be proportional to the expected payoff



Nondeterministic Games with Partial Observability

- E.g., card games, where opponent's initial cards are unknown
- Typically we can calculate a probability for each possible deal
- Seems just like having one big dice roll at the beginning of the game
- Idea: compute the minimax value of each action in each deal, then choose the action with highest expected value over all deals
- Special case: if an action is optimal for all deals, it's optimal.
- GIB, current best bridge program, approximates this idea by
  - 1) generating 100 deals consistent with bidding information
  - 2) picking the action that wins most tricks on average
    - "On average" as determined by Monte Carlo simulation, not a calculated expected value

Commonsense Example

- Day 1: Deterministic
  - Road A leads to a small heap of gold pieces (Eval = $1,000)
  - Road B leads to a fork:
    - take the left fork and you'll find a mound of jewels; (Eval = $1,000,000)
    - take the right fork and you'll be run over by a bus.

Commonsense Example

- Day 1: Deterministic
  - Road A leads to a small heap of gold pieces (Eval = $1,000)
  - Road B leads to a fork:
    - take the left fork and you'll find a mound of jewels; (Eval = $1,000,000)
    - take the right fork and you'll be run over by a bus.



- Day 2: Deterministic
  - Road A leads to a small heap of gold pieces (Eval = $1,000)
  - Road B leads to a fork:
    - take the left fork and you'll be run over by a bus;
    - take the right fork and you'll find a mound of jewels. (Eval = $1,000,000)


Commonsense Example

- Day 1 - Deterministic:
  - Road A leads to a small heap of gold pieces (Eval = $1,000)

  - Road B leads to a fork:
    - take the left fork and you'll find a mound of jewels; (Eval = $1,000,000)

    - take the right fork and you'll be run over by a bus.


- Day 2 - Deterministic:
  - Road A leads to a small heap of gold pieces (Eval = $1,000)

  - Road B leads to a fork:
    - take the left fork and you'll be run over by a bus;


    - take the right fork and you'll find a mound of jewels. (Eval = $1,000,000)

- Day 3 – Stochastic (50/50 chance on the road B fork):
  - Road A leads to a small heap of gold pieces (Eval = $1,000)

  - Road B leads to a fork:
    - guess correctly and you'll find a mound of jewels; (Eval = $1,000,000)

    - guess incorrectly and you'll be run over by a bus.


Proper Analysis

- Intuition that the value of an action is the average of its values in all actual states is WRONG
- With partial observability, value of an action depends on the information state or belief state the agent is in
- Can generate and search a tree of information states
- Leads to rational behaviors such as
  - Acting to obtain information
  - Signaling to one's partner
  - Acting randomly to minimize information disclosure
  - Cooperation and/or alliances

Summary

- Games are fun to work on! (and dangerous)
- They illustrate several important points about AI
  - Perfection is unattainable => must approximate
  - Good idea to think about what to think about
  - Uncertainty constrains the assignment of values to states
  - Optimal decisions depend on information state, not real state

Semester Project

- In the past weeks we've talked about characteristics of agents and of environments
- We've seen the effect of nondeterminism and partial observability on search efforts
- With these in mind, it's time to start talking about what we want to choose for the semester project