Games

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Announcements

- Programming Assignment 1: Search
  – Still in progress
  – A note about designing heuristics:
    - Add a "feature" at a time
    - Consider different weights for different features
    - Think beyond adding heuristic information together
    - Once you have a function that works well, remove elements to determine whether you really need them

Today

- Games (repeated from last time)
  – Planning/problem solving in the presence of an adversary ➔ adversarial search
  – Why games?
    - Easy to measure success or failure
    - States and rules are generally easy to specify
    - Interesting and complex
      – Space and time complexity
      – Uncertainty of adversaries' action, rolls of dice, etc.

Go

- AlphaGo became the first program to beat a human professional Go player without handicaps on a full 19x19 board.
- In go, b > 300
- Uses Monte Carlo tree search to select moves.
- Uses knowledge learned from a combination of reinforcement and deep learning.

Backgammon

- TDGammon uses depth-2 search + very good evaluation function + reinforcement learning (Gerry Tesauro, IBM)
- World-champion level play
- 1st AI world champion in any game!

[Adapted from CS 188 Berkeley]

Poker

- Libratus [Sandholm and Brown, CMU] won $1.7m (in chips) from 4 professional poker players over 20 days in January 2017
- No-limit Texas Hold'em
- Hard because it's a game of imperfect information. Can't see the opponent's hand.
- The "final frontier" in games…

Types of Games

	Deterministic	Chance
Perfect Information	Chess, Checkers, Go, Connect Four	Backgammon
Imperfect Information	Battleship, Guess Who?	Bridge, Poker, Scrabble

[Adapted from Russell and from CS 188 Berkeley]

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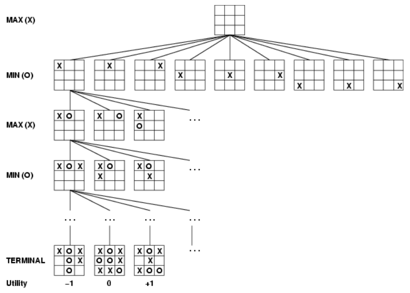
Want algorithms for calculating a strategy (policy) that recommends a move in each state

[Adapted from Russell and from CS 188 Berkeley]

Connect Four Demo

- With perfect play, first player can force a win by starting in the middle column.
- By starting in one of the two adjacent columns, the first player allows the second player to reach a draw.
- By starting in any of the four outer columns, the first player allows the second player to force a win.
- There exist perfect players – my demo program is not one of them.

Game Playing as a Search Problem



Note that each level in the game tree (i.e., each half move) is called a **ply**.

Formulating Game Playing as Search

- States S
  - Description of the current state/configuration of the game
- Players P = {1, 2, …, n}
  - Will take turns in the games we consider
- Actions A
  - Legal actions may depend on player and state
- Transition model
  - Defines the result of an action applied to a state for a particular player
  - Result is a new state
- Terminal test
  - Function on states; returns T if state is a terminal state and F otherwise
- Utility function S x P -> value
  - Also called objective function or payoff function

[Adapted from CS 188 Berkeley]

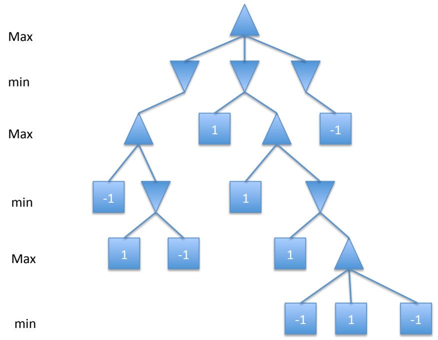
Games vs Search Problems

- "Unpredictable" opponent ⇒ solution is a strategy
- Time limits ⇒ unlikely to reach terminal states.
  - Must approximate

Minimax Search

- When it's your turn, generate (ideally) the complete game tree.
- Select the move that is best for you, assuming that your opponent will, at each opportunity, select the move that is worst for you (and thus best for him/her/itself)

An Example: 2-player zero-sum game



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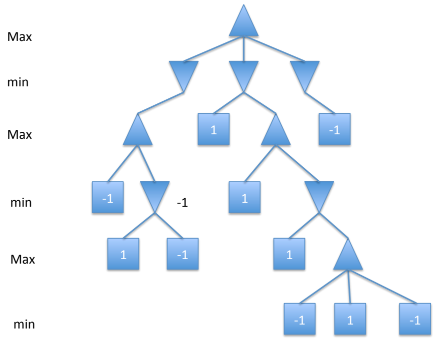

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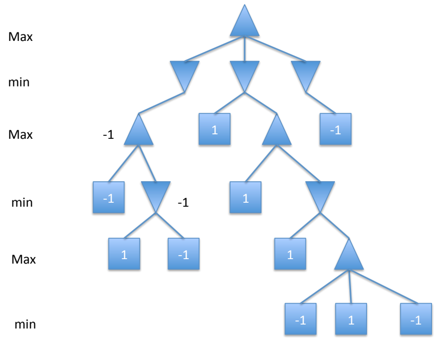

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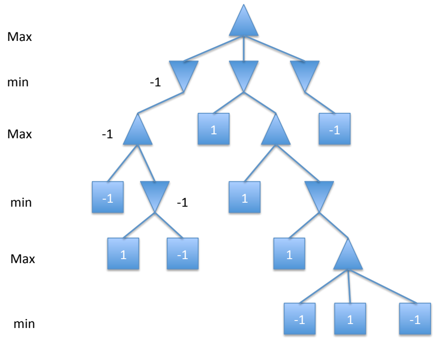

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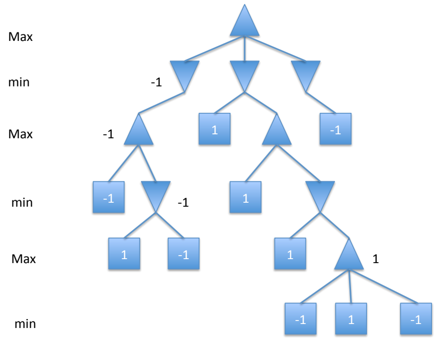

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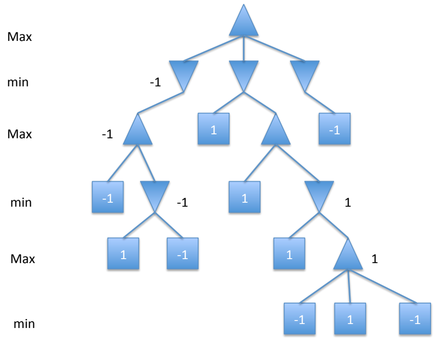

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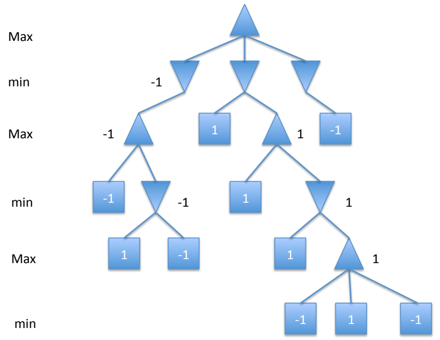

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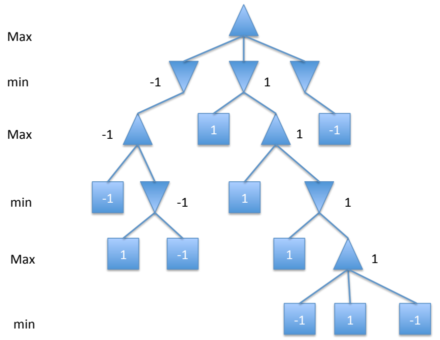

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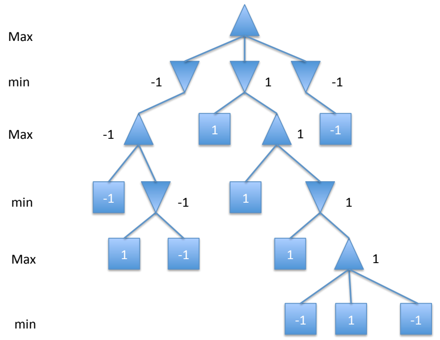

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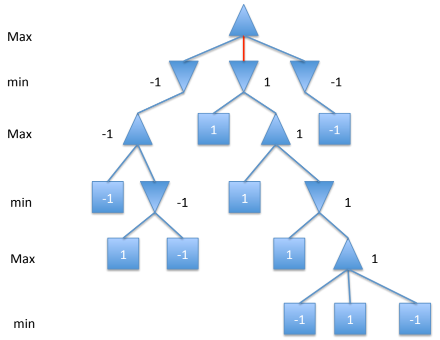
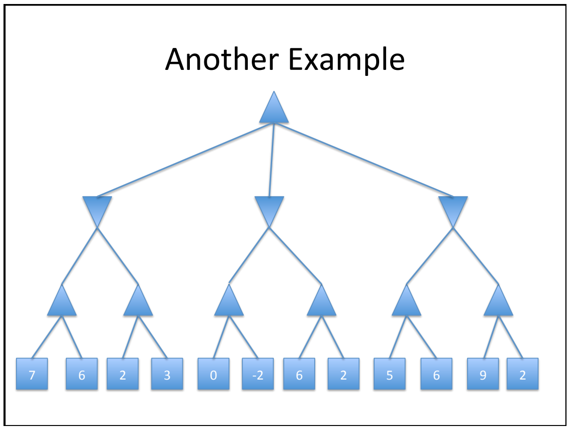


Minimax Search revisited

- A state-space search tree
- Players alternate turns
- Each node has a **minimax value**: best achievable utility against a rational adversary

[Adapted from CS 188 Berkeley]



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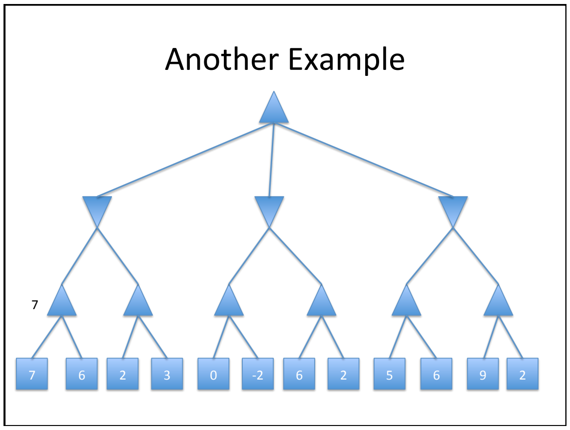

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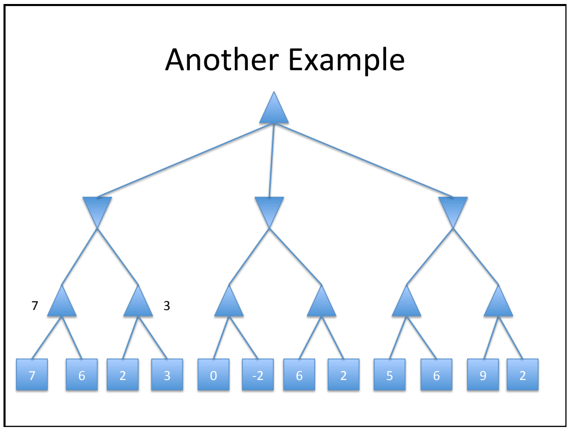

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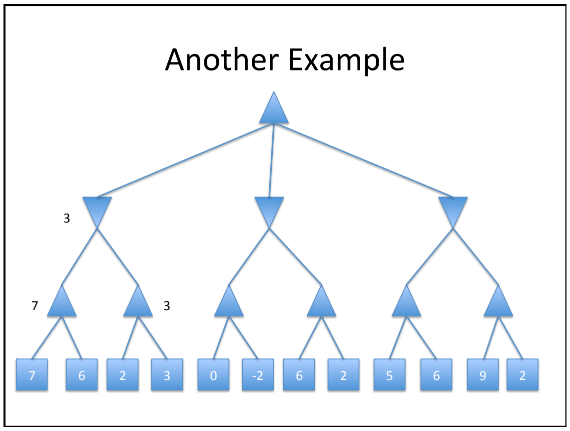

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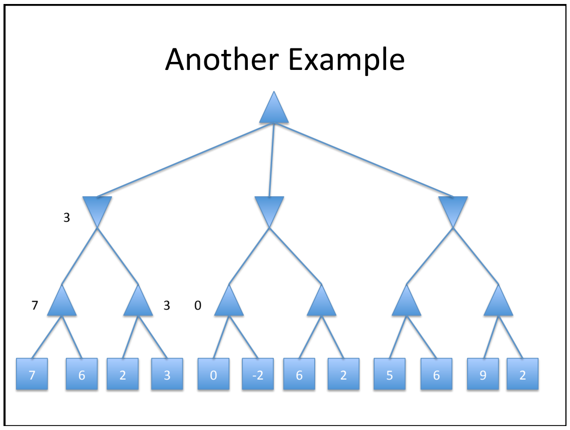

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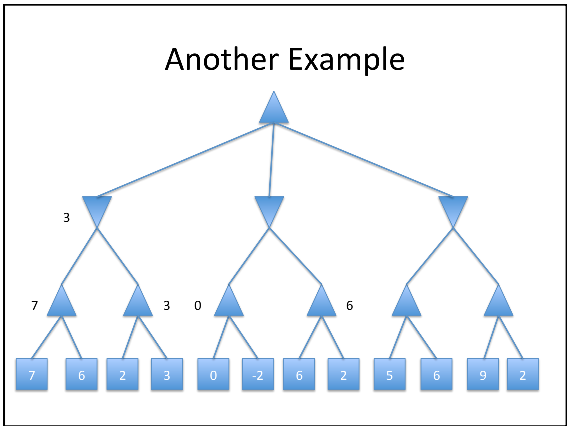

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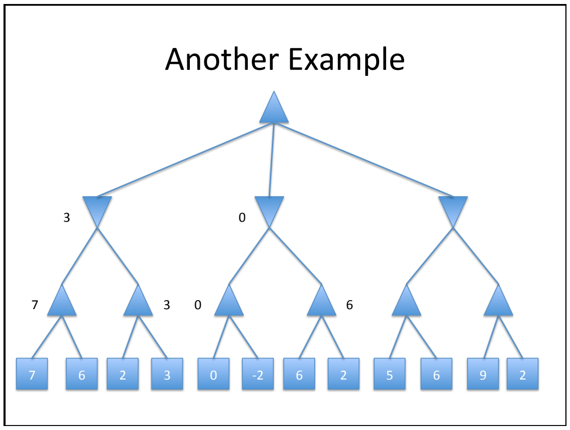

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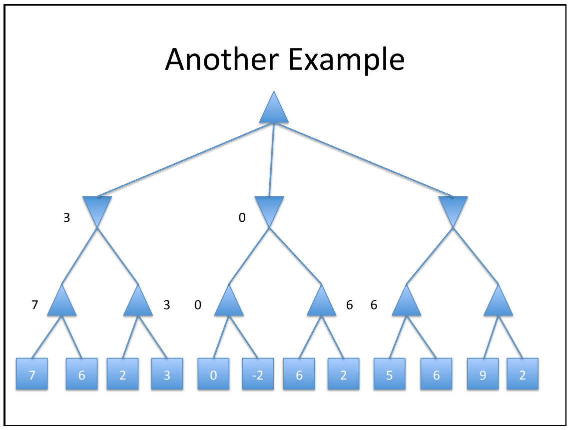

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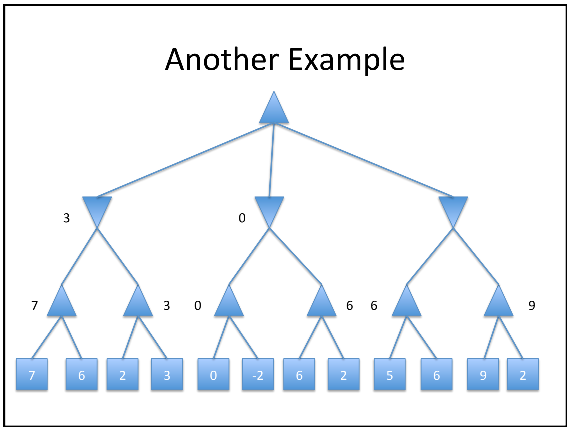

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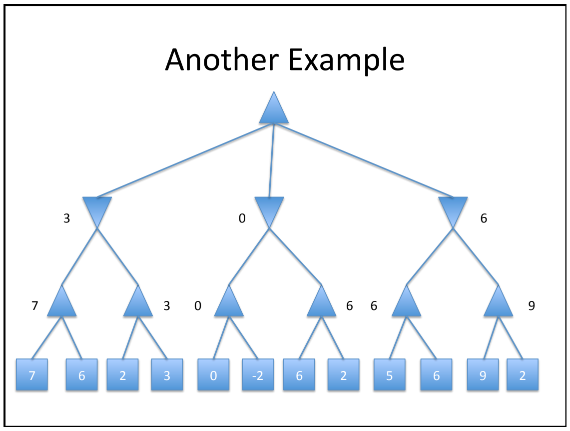

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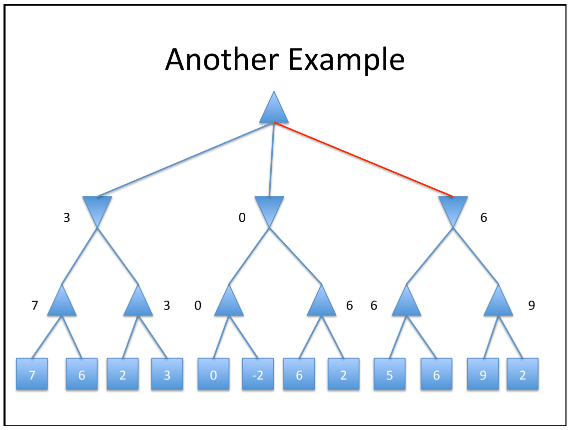

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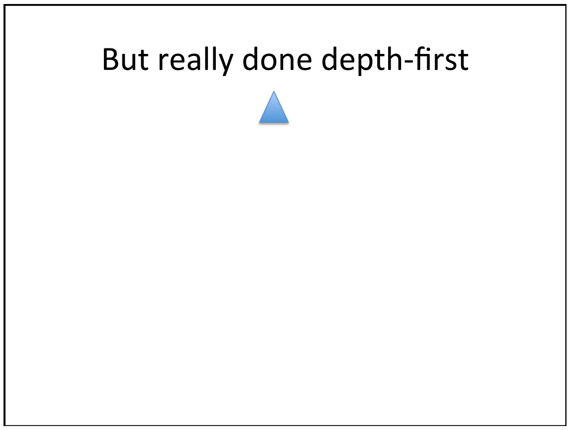

But really done depth-first

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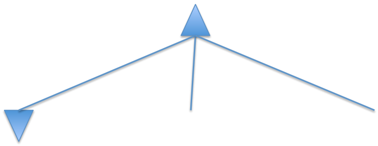

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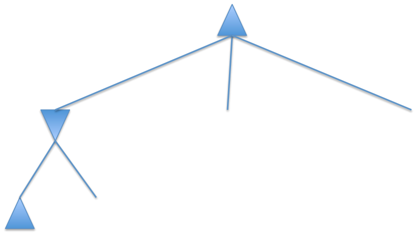

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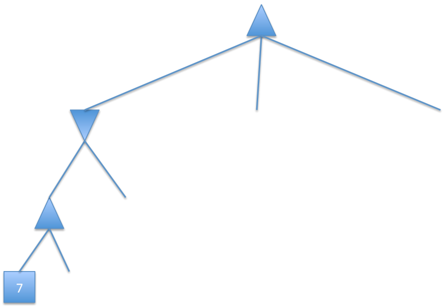

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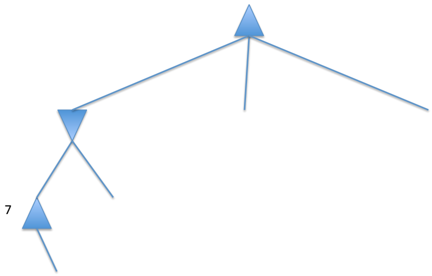

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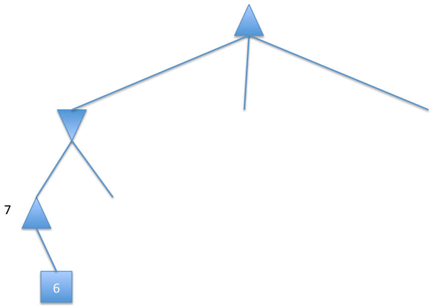

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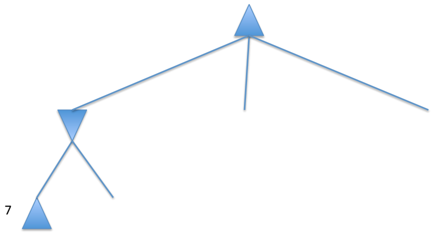

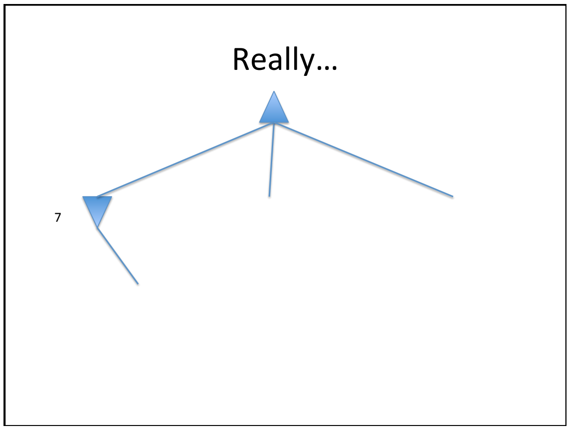

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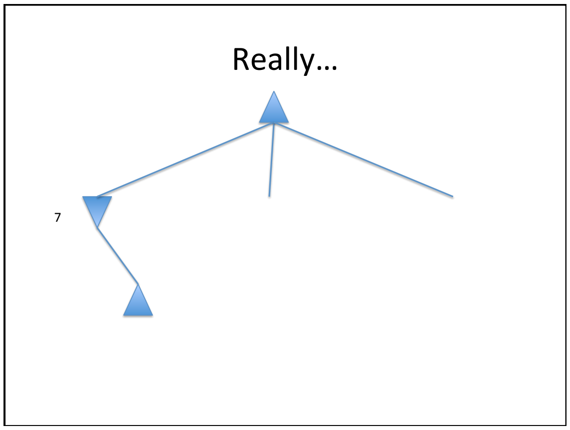

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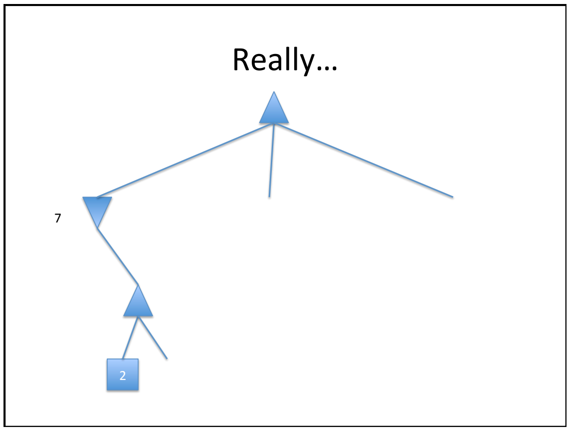

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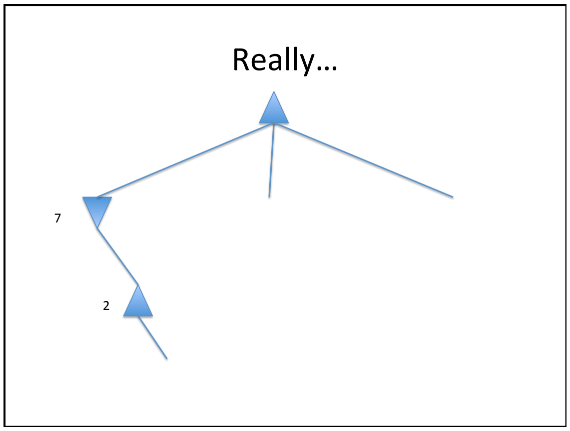

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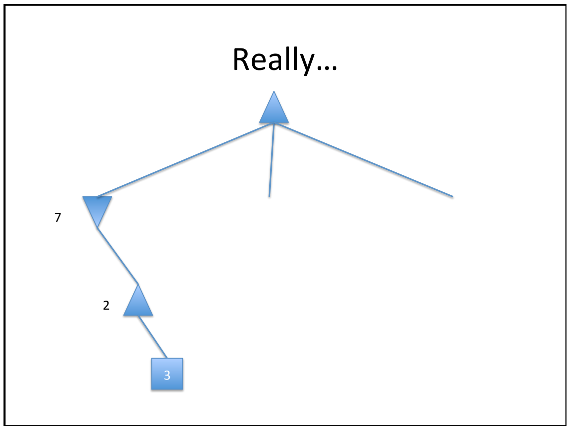

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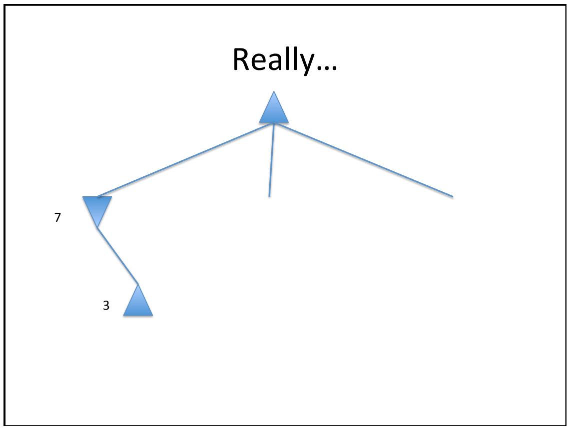

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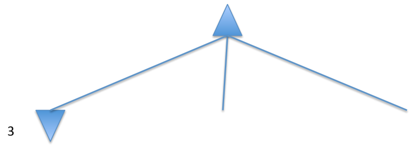

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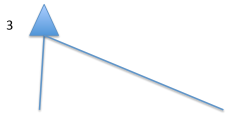

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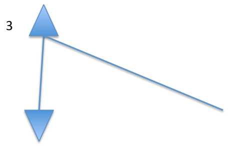

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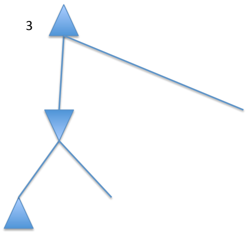

```
function MINIMAX-DECISION(state) returns an action a
  return arg max a in ACTIONS(state) MIN-VALUE(RESULT(state, a))


function MIN-VALUE(state) returns a utility value v
   if TERMINAL-TEST(state) then return UTILITY(state)
   v = infinity
   for each a in ACTIONS(state) do
      v = MIN(v, MAX-VALUE(RESULT(state, a)))
   return v


function MAX-VALUE(state) returns a utility value v
   if TERMINAL-TEST(state) then return UTILITY(state)
   v = -infinity
   for each a in ACTIONS(state) do
      v = MAX(v, MIN-VALUE(RESULT(state, a)))
   return v
```

Minimax Reality

- Can rarely explore entire search space to terminal nodes.
  - DFS has good space complexity, but bad time complexity
- Choose a depth cutoff – i.e., a maximum ply
- Need an evaluation function
  - Returns an estimate of the expected utility of the game from a given position
  - Must order the terminal states in the same way as the true utility function
  - Must be efficient to compute
    - Trading off plies for heuristic computation
    - More plies makes a difference
- Consider iterative deepening

Evaluation Functions

- Ideal: returns the utility of the position
- In practice: typically weighted linear sum of features:
- Eval(*s*) = $w_1 f_1(s) + w_2 f_2(s) + \ldots + w_n f_n(s)$

Exercise

- Evaluation function for Connect Four?