For Friday

- Finish chapter 6
- No homework
- Program 1, milestone 1 due

Program 1

- Any questions?

8-Puzzle Heuristic Functions

- Number of tiles out of place
- Manhattan Distance
- Which is better?
- Experiment
- Effective branching factor

Inventing Heuristics

- Relax the problem
- Cost of solving a subproblem
- Learn weights for features of the problem

Local Search

- Works from the “current state”
- No focus on path
- Also useful for optimization problems

Local Search

- Advantages?
- Disadvantages?

Hill-Climbing

- Also called gradient descent
- Greedy local search
- Move from current state to a state with a better overall value
- Issues:
  - Local maxima
  - Ridges
  - Plateaux

Variations on Hill Climbing

- Stochastic hill climbing
- First-choice hill climbing
- Random-restart hill climbing

Evaluation of Hill Climbing

Simulated Annealing

- Similar to hill climbing, but--
  - We select a random successor
  - If that successor improves things, we take it
  - If not, we may take it, based on a probability
  - Probability gradually goes down

Local Beam Search

- Variant of hill-climbing where multiple states and successors are maintained

Genetic Algorithms

- Have a **population** of k states (or **individuals**)
- Have a **fitness function** that evaluates the states
- Create new individuals by randomly selecting pairs and mating them using a randomly selected **crossover point**.
- More fit individuals are selected with higher probability.
- Apply random **mutation**.
- Keep top k individuals for next generation.

Other Issues

- What issues arise from continuous spaces?
- What issues do online search and unknown environments create?

Game Playing in AI

- Long history
- Games are well-defined problems usually considered to require intelligence to play well
- Introduces uncertainty (can’t know opponent’s moves in advance)

Games and Search

- Search spaces can be very large:
- Chess
  - Branching factor: 35
  - Depth: 50 moves per player
  - Search tree: 35^{100} nodes (~10^{40} legal positions)
- Humans don’t seem to do much explicit search
- Good test domain for search methods and pruning methods

Game Playing Problem

- Instance of general search problem
- States where game has ended are terminal states
- A utility function (or payoff function) determines the value of the terminal states
- In 2 player games, MAX tries to maximize the payoff and MIN is tries to minimize the payoff
- In the search tree, the first layer is a move by MAX and the next a move by MIN, etc.
- Each layer is called a ply

Minimax Algorithm

- Method for determining the optimal move
- Generate the entire search tree
- Compute the utility of each node moving upward in the tree as follows:
  - At each MAX node, pick the move with maximum utility
  - At each MIN node, pick the move with minimum utility (assume opponent plays optimally)
  - At the root, the optimal move is determined

Recursive Minimax Algorithm

```
function Minimax-Decision(game) returns an operator
    for each op in Operators[game] do
        Value[op] <- Mimimax-Value(Apply(op, game),game)
    end
    return the op with the highest Value[op]

function Minimax-Value(state,game) returns a utility value
    if Terminal-Test[game](state) then
        return Utility[game](state)
    else if MAX is to move in state then
        return highest Minimax-Value of Successors(state)
    else
        return lowest Minimax-Value of Successors(state)
```

Making Imperfect Decisions

- Generating the complete game tree is intractable for most games
- Alternative:
  - Cut off search
  - Apply some heuristic evaluation function to determine the quality of the nodes at the cutoff

Evaluation Functions

- Evaluation function needs to
  - Agree with the utility function on terminal states
  - Be quick to evaluate
  - Accurately reflect chances of winning
- Example: material value of chess pieces
- Evaluation functions are usually weighted linear functions

Cutting Off Search

- Search to uniform depth
- Use iterative deepening to search as deep as time allows (anytime algorithm)
- Issues
  - quiescence needed
  - horizon problem