Artificial Intelligence

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Learning Outcomes of Search Agents

- Informed search
  - Also called blind search
  - The strategies have no additional information about states beyond that provided in the problem definition
  - Depth-first search
  - Breadth-first search
  - Uniform-cost search

- Informed search
  - Also called heuristic search
  - The strategies know whether one non-goal node is “more promising” than another
  - Greedy best-first search
  - A* search

- Reference reading
  - Chapter 3
Admissible Heuristic of A* Search

- The tree-search version of A* is optimal if $h(n)$ is admissible
  - Evaluation function: $f(n) = g(n) + h(n)$
  - $g(n)$: the cost so far to reach the node n
  - $h(n)$: the estimated cost to goal from the node n
  - $f(n)$: the estimated total cost of path through the node n to goal

- An admissible heuristic never overestimates the cost to reach the goal
  - A heuristic $h(n)$ is admissible if for every node n, $h(n) \leq h^*(n)$, where $h^*(n)$ is the true cost to reach the goal state from n.
Domination of Heuristic Functions

- If \( h_2(n) \geq h_1(n) \) for all \( n \) (both admissible)
  - then \( h_2 \) dominates \( h_1 \), which indicates that \( h_2 \) is better for search
- Domination translates directly into efficiency
  - \( A^* \) using \( h_2 \) will never expand more nodes than \( A^* \) using \( h_1 \).

\[ h_1(S) = 8 \]
\[ A^*(h_1) = 39,135 \text{ nodes} \]
\[ h_2(S) = 18 \]
\[ A^*(h_2) = 1,641 \text{ nodes} \]
N-queens Problem

- Put $n$ queens on an $n \times n$ board with no two queens on the same row, column, or diagonal
- Move a queen to reduce number of conflicts
Place 8-queens on a chessboard such that no queen attacks any other

- A queen attacks any piece in the same row, column, or diagonal
Local Search

- Problem: Romania
  - The search algorithms explore search space systematically
  - When a goal is found, the path to the goal also constitutes a solution to the problem

- Problem: N-Queens
  - The path to the goal is irrelevant

- Local search
  - Operate using a single current node
  - Generally move only to neighbors of that node
  - Useful to find the best state according to an objective function
State-space Landscape

- Location: defined by the state
- Evaluation: defined by the value of the objective function
Hill-climbing Search

- Depending on initial state, can get stuck in local maxima
Arthur Samuel

- Professor at Stanford University
- Proposed hill-climbing search in 1963
  - Made the first computer checker program on IBM's first commercial
- Applications of hill-climbing search
  - Network flow problem
  - VLSI (Very Large Scale Integration) design
Simulated Annealing Search

- **Hill-climbing**
  - Never makes downhill moves
  - Get stuck on a local maximum

- **Random walk**
  - Moving to a successor chosen uniformly at random
  - Is complete but extremely inefficient

- **Simulated annealing**
  - Escape local maxima by allowing some "bad" moves but gradually decrease their frequency
  - In metallurgy, annealing is the process used to temper or harden metals and glass by heating them to a high temperature and then gradually cooling them
  - The algorithm is quite similar to hill-climbing
    - Instead of picking the best move, it picks a random move
    - If the move improves the situation, it is always accepted
Simulated Annealing Search

Sept. 15, 2015  Local Algorithms  12
Simulated Annealing Search Proposed in 1983

- Scott Kirkpatrick
  - Ph.D. in Physics from Harvard University
- C. Daniel Gelatt, JR
  - PhD in Physics from Harvard University
- Mario P. Vecchi
  - PhD in Electrical Engineering from Massachusetts Institute of Technology