Informed Searches

• Greedy Best-First Search
• A*
• Improvements to A*

Review: Tree Search

A strategy is defined by picking the order of node expansion

Best-First Search

• Evaluation Function for each node – estimating desirability.
• Expand most desirable unexpanded node
• Implementation – use a queue! Sort by desirability.
• Specific Cases:
  ▪ Greedy
  ▪ A*

Greedy Best-first Search

• Greedy – expand the node that is closest to the goal.
• \( f(n) = h(n) = \text{estimate of cheapest path} \)
• Example: Romanian Vacation Problem
  \[ h_{sl} = \text{Straight line distance between two cities} \]
• Take home – Greedy expands the node that appears to be the closest to the goal.
Analysis of Technique

- Complete – nope, can run into loops (example: take RVP with Oradea as goal)
- Time – $O(b^m)$, though heuristics can improve this
- Space – $O(b^m)$, all states in memory
- Optimal – not necessarily

$A^*$

- An extension of Dijkstra’s shortest path algorithm developed by Hart, Nilsson, and Raphael (SRI).
- General Idea: try not to go down the expensive paths!
- Evaluation function:
  $$f(n) = h(n) + g(n)$$
  where $h(n)$ = estimated cost from n to goal
  $g(n)$ = cost so far to reach n
- $A^*$ uses an admissible heuristic – one that never overestimates the cost to reach the goal.
Exercise!

- Here’s a starter 8-puzzle. How would A* solve this puzzle? What’s the heuristic?

```
4 3 7
2 1
3 6 8
```

Analysis of Technique

- Complete – yes, assuming finite number of states
- Time – potentially exponential – why so long?
  - while efficient and optimal, the number of potential states (think: paths) that have to be expanded/searched is still exponential.
- Space – $O(b^m)$, all states in memory
- Optimal – yes!

Some additional terminology

- Dominance – assuming that we have admissible heuristics, if $h_2(n) \geq h_1(n)$ for any node $n$, then $h_2(n)$ dominates $h_1(n)$ and is “better”.
- Consistency (aka monotonicity) – a heuristic is consistent if, for every node $n$ and every successor $n'$ of $n$ generated by any action $a$, the estimated cost of reaching the goal from $n$ is no greater than the step cost of getting to $n'$ plus the estimated cost of reaching the goal from $n'$.
- Relaxed problems

Memory-bounded Heuristic

- One issue with A* - memory usage!
- Briefly – Iterative-Deepening A* (IDA*)
  - Iterative Deepening Search (see last set of slides)
  - Cutoff used – $f(n)$ rather than the depth
- Recursive best-first search (RBFS) – simple recursive algorithm for BFS in linear space.
- Memory-Bounded A* (MA*) & Simplified MA* (SMA*) – A* until memory is full, then expand by dropping the “worst” leaf node.