Informed Search

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DFS: (Reprise) Time

worst case:
solution on this branch

$O(b^{d+1} - b^{d-m}) = O(b^{d+1})$

BFS (Reprise): Time

$O(b^{m+1})$

DFS (Reprise): Space

worst case:
search is here

$b-1$ nodes open at each level

d levels

$O((b-1)d) = O(bd)$
BFS: (Reprise) Space

IDS (Reprise)

IDS (Reprise)

Informed Search

What if we know something about the search?
Informed Search

Key thing in search is managing the frontier.

Use domain knowledge to order the nodes that you open.

Heuristics

Key idea: heuristic function.

- $h(s)$ - estimates cost-to-go
- Cost to go from state to solution.
- Problem specific.

Greed

What if we expand the node with lowest $h(s)$?

A*

A* algorithm:

- Also $g(s)$ - cost so far (start to $s$).
- Expand $s$ that minimizes $g(s) + h(s)$
- Manage frontier as priority queue.

- Admissible heuristic: never overestimates cost.
  
  $h(s) \leq h^*(s)$

- $h(s) = 0$ if $s$ is a goal state, so $g(s) + h(s) = c(s)$

- If $h$ is admissible, A* is optimal.
- If $h(s)$ is exact, runs in $O(bd)$ time.
Admissible Heuristics

Proof by contradiction.

suboptimal $c(s)$

optimal $c^*(s)$

common ancestor

Example Heuristics

Example Heuristic

More on Heuristics

Heuristic $h_1$ dominates $h_2$ if $h_1(s) \geq h_2(s)$ for all $s$.
- Is $h_1$ or $h_2$ better? (If they’re both admissible.)

How might you combine two heuristics?

What is $h(s) = k$ (constant) for all $s$?
More on Heuristics

A* is optimally efficient: any algorithm using $h$ must expand the nodes A* expands.

Why?

More on Heuristics

Ideal heuristics:
- Fast to compute.
- Close to real costs.
- Some programs *automatically generate* heuristics.