# Informed Search

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DUKE COMPUTER SCIENCE

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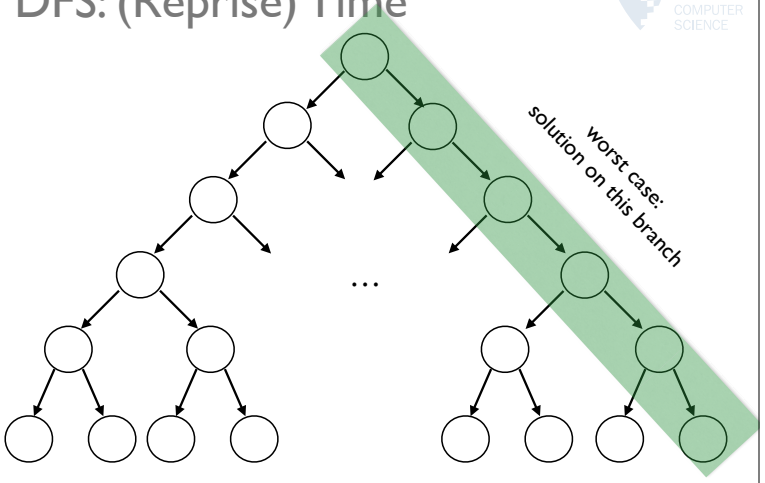
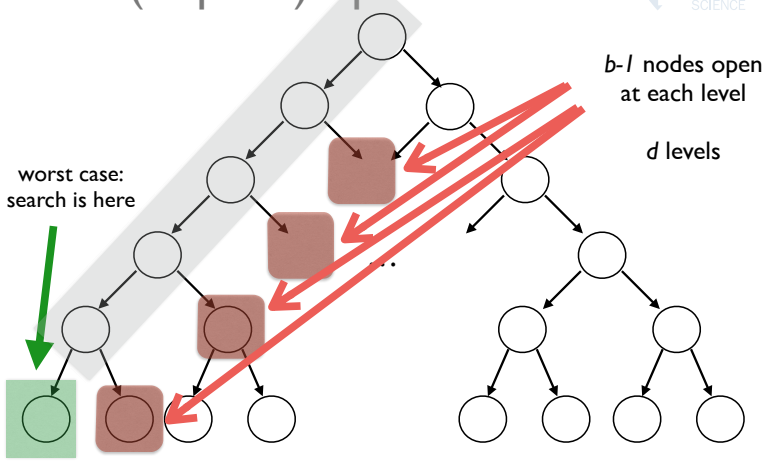
## DFS: (Reprise) Time



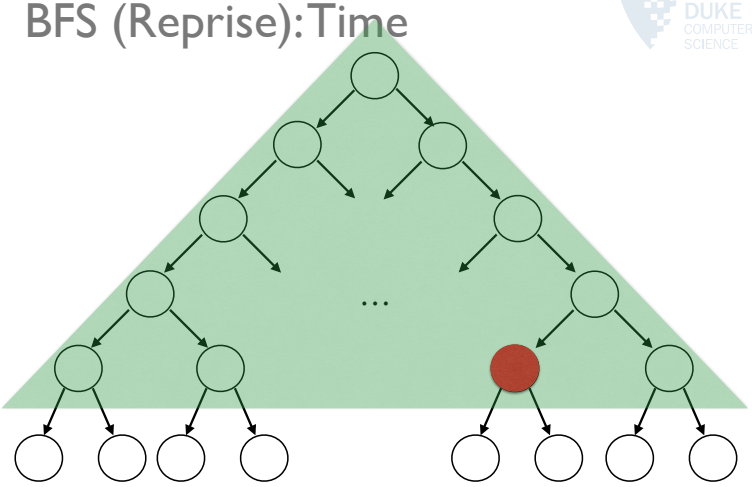

$O(b^{d+1} - b^{d-m}) = O(b^{d+1})$

## DFS (Reprise): Space



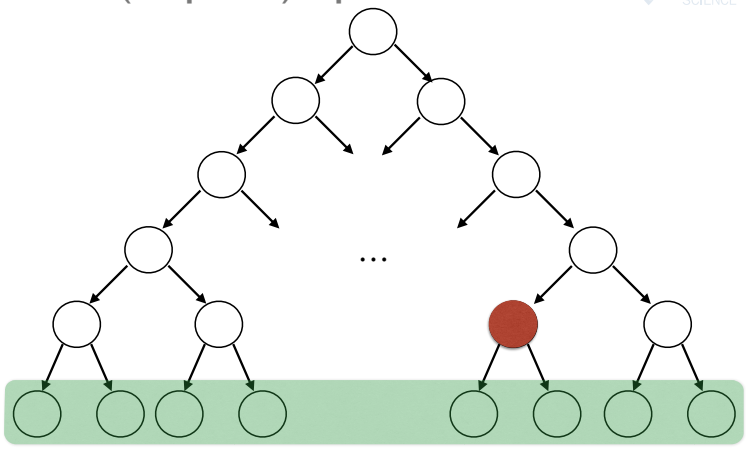

$O((b-1)d) = O(bd)$

## BFS (Reprise): Time



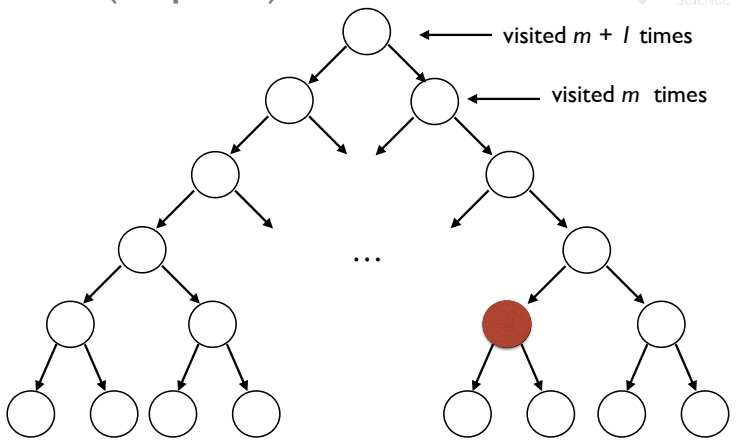

$O(b^{m+1})$

## BFS: (Reprise) Space



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

## IDS (Reprise)

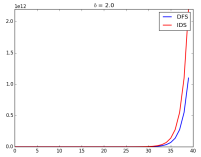



## IDS (Reprise)

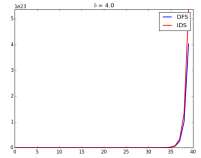
$$\sum_{i=0}^{m} b^i(m-i+1) = \frac{b(b^{m+1}-m-2)+m+1}{(b-1)^2}$$

# nodes at level *i*

# revisits

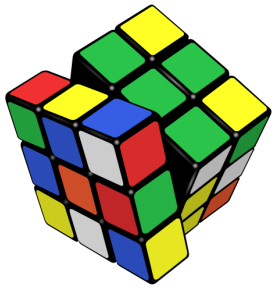


DFS worst case: $\frac{b^{m+1}-1}{b-1}$



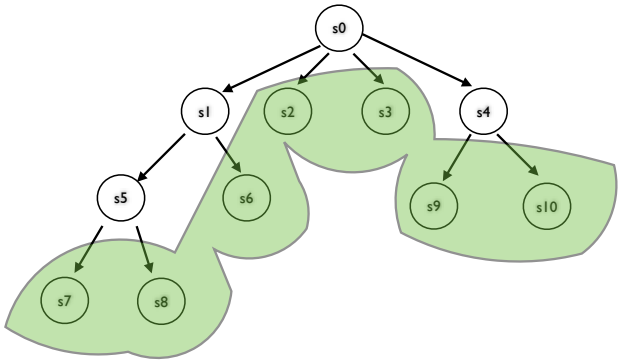
## Informed Search

What if we *know something* about the search?



# Informed Search

Key thing in search is *managing the frontier.*

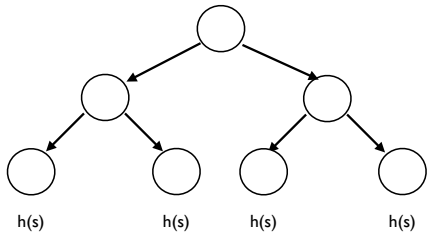



*Use domain knowledge to order the nodes that you open.*

# Heuristics

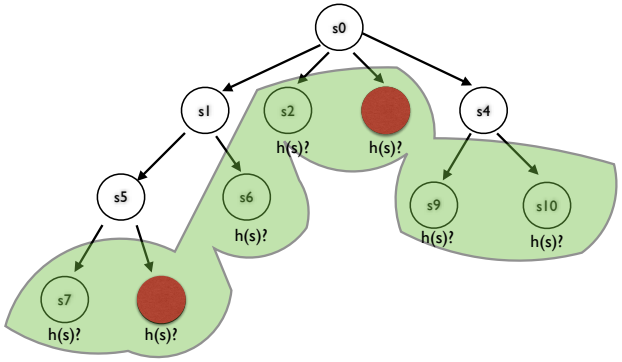
Key idea: *heuristic function*.

- *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.

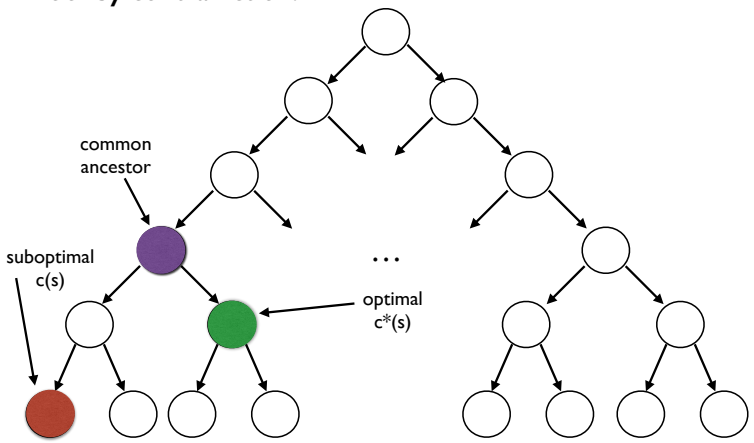
$$h(s) \leq h^*(s)$$

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

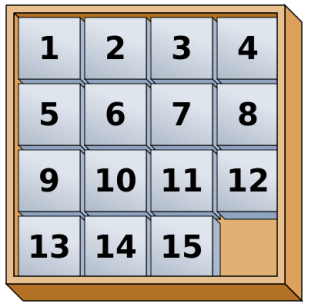
- If h is admissible, A* is optimal.
- If h(s) is exact, runs in *O(bd)* time.

# Admissible Heuristics

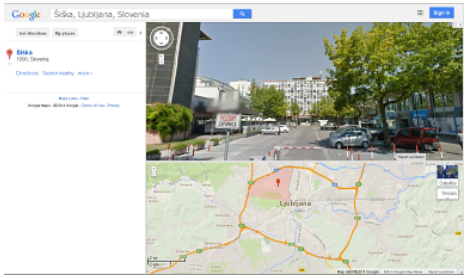
**Proof by contradiction.**




# Example Heuristic




# Example Heuristics



# More on Heuristics

Heuristic *h1* dominates *h2* if *h1(s)* >= *h2(s)* for all s.

- Is *h1* or *h2* 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.