CS 4100/5100: Foundations of AI

Classical Search

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The search problem

Suppose our problem is:

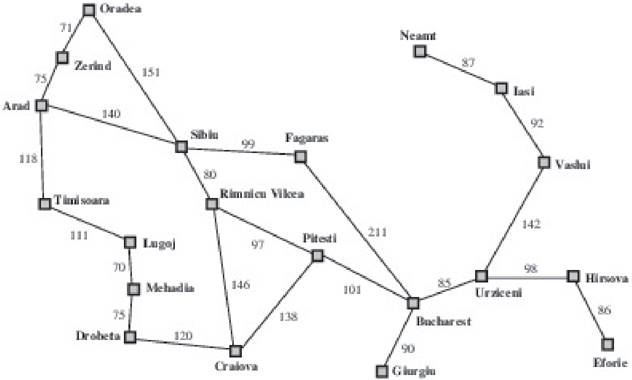
- fully observable
- discrete
- known (modeled)
- deterministic

Then, we can use classical search!

Assume we are given:

- a known initial state
- a set of actions and a model of the effects of those actions (the transition model)
- cost function
- goal test

An example of a search problem



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- discrete?
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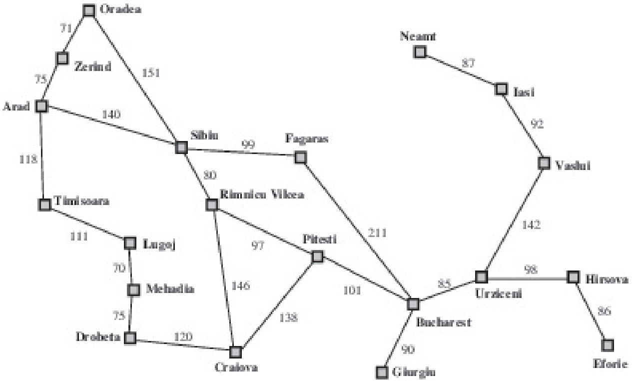
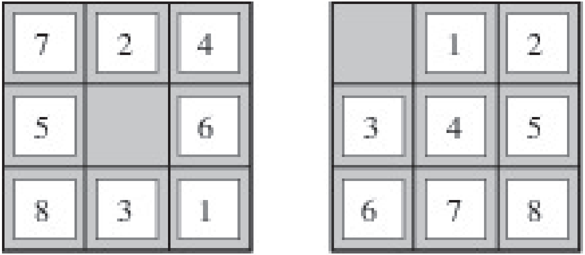


- initial state?
- actions, transition model?
- cost function?
- goal test?

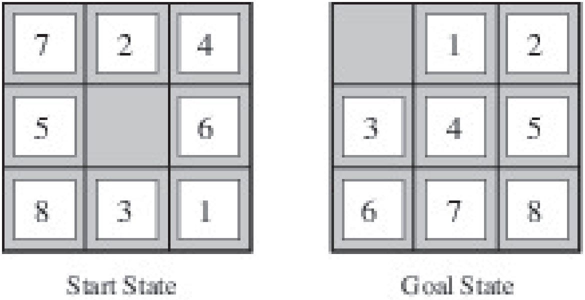
Another example of a search problem



Start State Goal State

- fully observable?
- discrete?
- known (modeled)?
- deterministic?

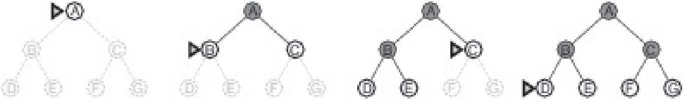
Another example of a search problem



- initial state?
- actions, transition model?
- cost function?
- goal test?

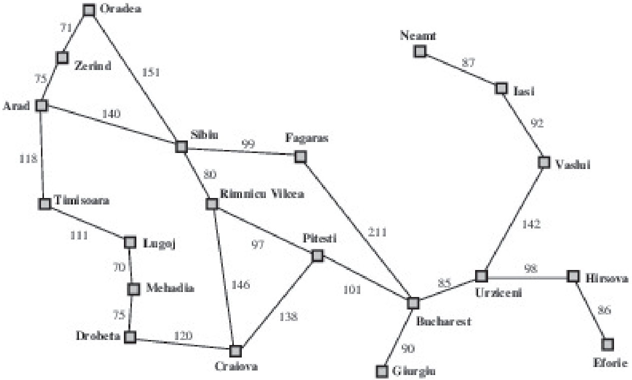
Breadth-first search (BFS)

Search strategy: expand *shallowest* node first.



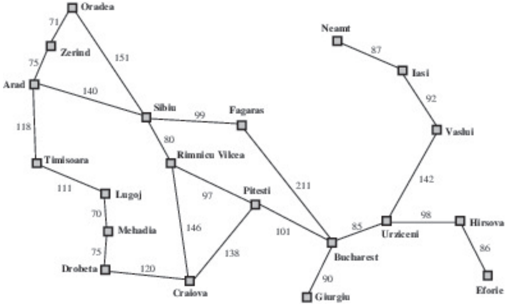
- This is an *uninformed* search strategy. Why?
- Where/what is the *frontier*?
- BFS can be implemented by a FIFO queue of frontier nodes (illustrate on the board).
- Computational complexity: How big does the FIFO queue get for a graph w/ branhcing factor b and maximum depth d?
  - what is the asymptotic complexity?
- Is BFS complete (is it guaranteed to find a path if one exists)? Is it optimal (does it find the shortest path to the goal)?
- For which problem is BFS appropriate?

Breadth-first search (BFS): example



Uniform-cost search (UCS)

But, does BFS make sense for the road map problem?

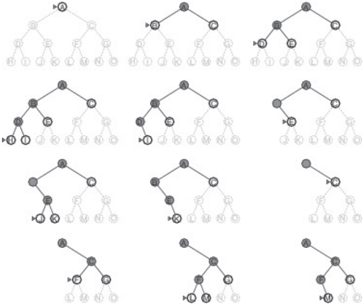


UCS: always choose to expand the frontier node w/ lowest cost.

- Generalizes BFS to graphs w/ weighted edges.
- Can be implemented by a priority queue.
- Computational complexity?

Depth first search (DFS)

What can we do to improve the space requirements of BFS?

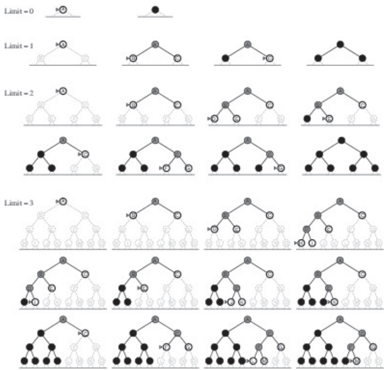


DFS: expand the *deepest* node first.

- what is the storage requirement w/ BFS (in terms of branching factor, b, and max depth, m)?
- what is the storage requirement w/ DFS?
- is it complete? optimal? Finite vs. infinite search spaces...

Iterative deepening search

Can we combine the space advantages of DFS w/ the optimality of BFS?



Iteratively do depth limited search (what's that?) w/ successively increasing depth limits

- what is the asymptotic complexity now?

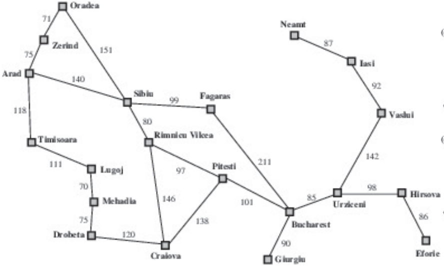
Heuristic search: greedy best-first search

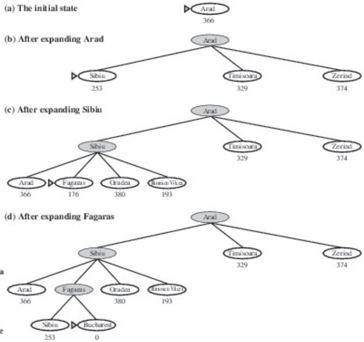
So far, we have covered covered *uninformed* search strategies, where search is undirected. But, what if we have heuristics that can guide search?

Greedy best-first search:

- Assume the search algorithm has access to a heuristic that evaluates how useful it will be to expand a particular fringe node.
- Always choose to expand the fringe node w/ the best heuristic value.

Greedy best-first search: example





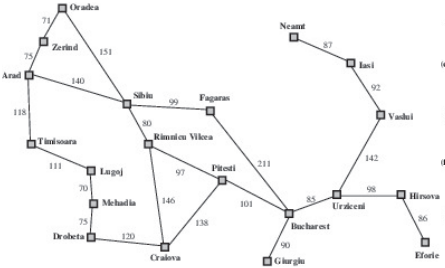
- Is this algorithm complete? Is it optimal?

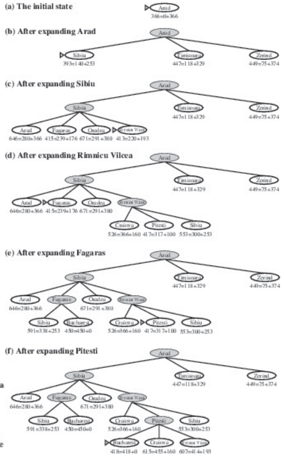
Heuristic search: A^*

Combine greedy search w/ UCS. Consider the application to search in a weighted graph:

- n: number of a particular node in the tree.
- $h(n)$: heuristic value of that node.
- $g(n)$: cost so far to get to that node.
- UCS: evaluate $g(n)$ for each node on fringe. Expand node w/ highest value.
- Greedy: evaluate $h(n)$ for each node on fringe. Expand node w/ highest value.
- A^*: evaluate $g(n) + h(n)$ for each node on fringe. Expand node w/ highest value.

A*: example





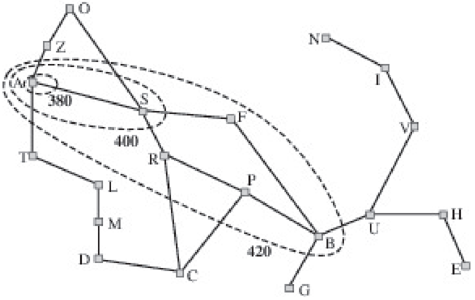
- Is this algorithm more or less efficient than UCS?
- Is this algorithm complete? Is it optimal?

Optimality of A*

The heursitic function needs to satisfy certain conditions in order for A* to be optimal:

- **Admissability**: the heuristic function cannot *overestimate* the cost to goal: the heuristic should be "optimistic".
  - what's an example of an admissible heuristic for the map problem?
- **Consistency** (monotonicity): $h(n) \leq c(n, a, n') + h(n')$.
  - This is a kind of triangle inequality.
  - If $h(n)$ is consistent, then the values of $h(n) + g(n)$ along any path are nondecreasing.

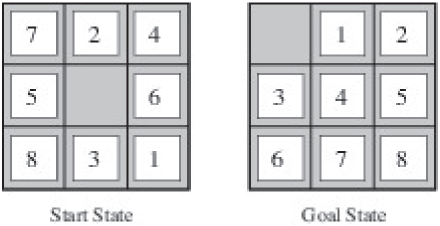
Optimality of A*



Map of Romania showing contours at f = 380, f = 400, and f = 420, with Arad as the start state. Nodes inside a given contour have f -costs less than or equal to the contour value.

- Notice that consistency implies admissability. Why?
- Notice that consistency implies optimality of A*. Why?

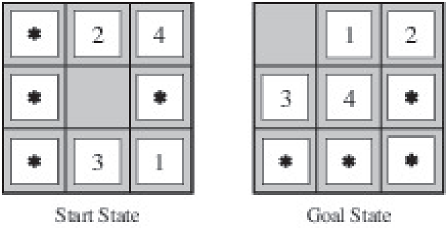
A^*: the power of heuristics



The 8-puzzle.
Are there general strategies for creating heuristics:

- Solve a *relaxed* version of the problem.
- Solve a subproblem.
- Can you suggest a good heuristic for the 8-puzzle?

A*: the power of heuristics



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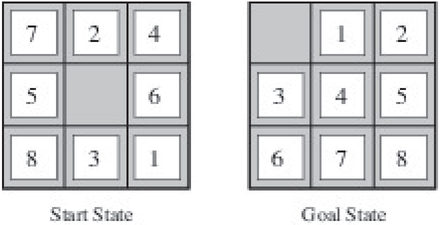

How many nodes are expanded to solve an 8-puzzle problem w/ optimal solution depth 12?

- IDS: 3.6M
- A^* w/ displaced tile heuristic: 227
- A^* w/ manhattan heuristic: 73