

Generic Search Algorithm and examples

CS 580

Intro to Artificial Intelligence

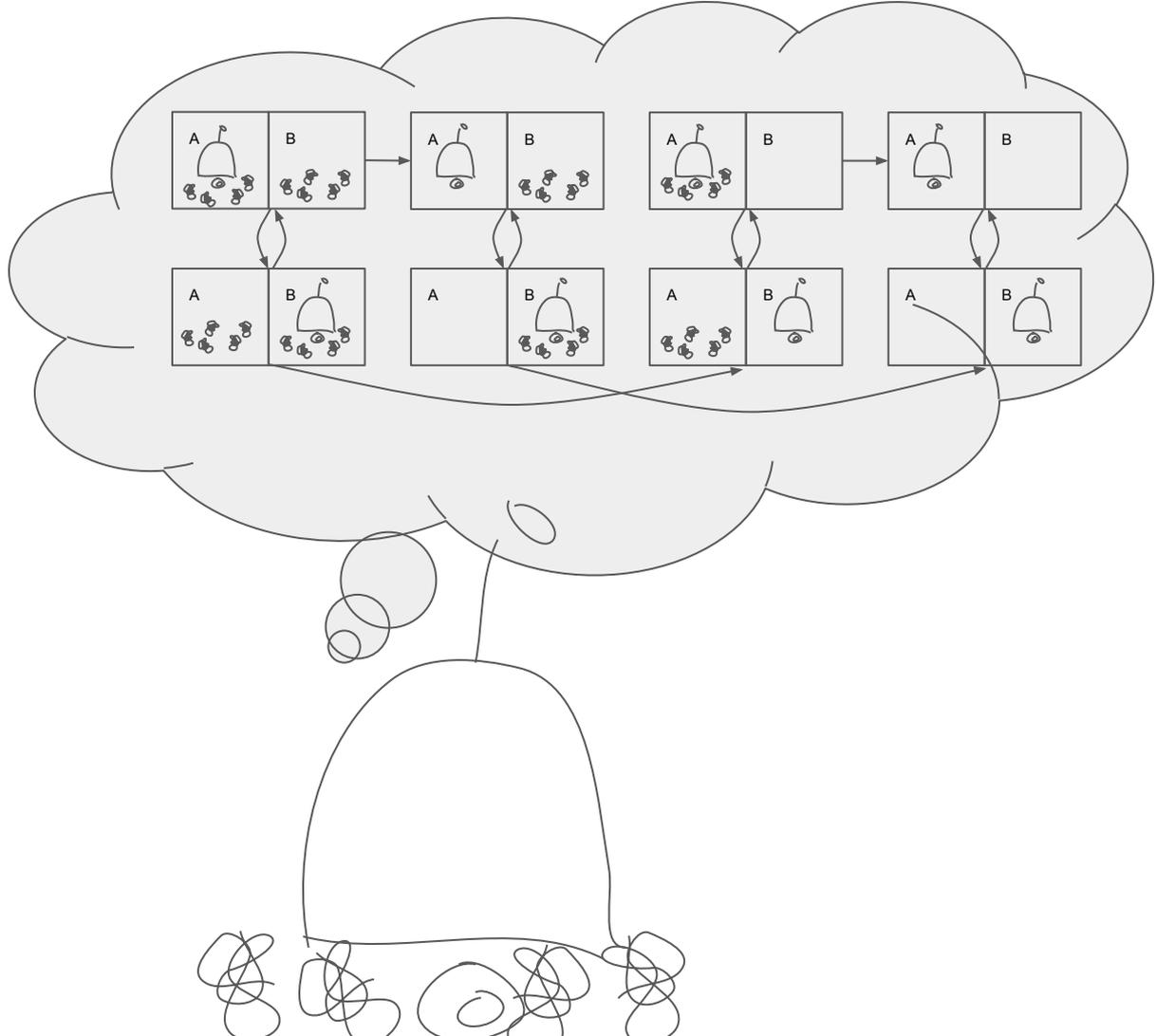
Recall

A Search Agent solves problems by

- Formulating a **state space** and **goal**
- Searching the state space until it has found a **sequence of actions** from the initial state to the goal
- **Executing** each action in turn

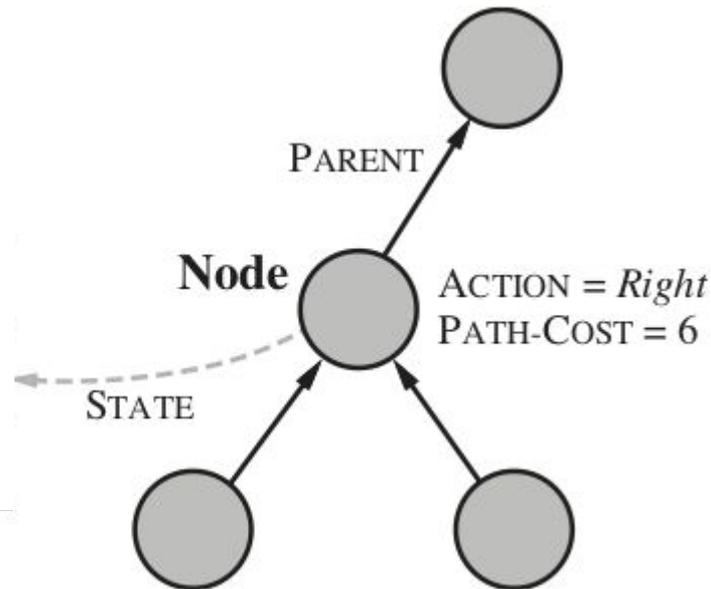
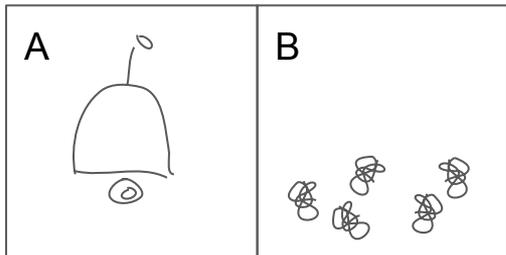
We know several ways of searching a state space

- Depth First Search
- Breadth First Search
- Uniform Cost Search

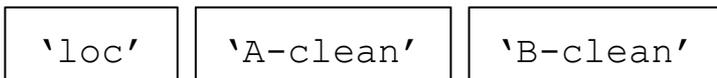


Search Node data structure

We've looked at the state space in the abstract as states connected by actions, but we need some additional bookkeeping to implement our search



- Parent **node** (for backtracking)
- Transition **action**
- Cost of shortest known path from start to this state, **g**
- The actual **state**



```
node=dict()  
node['state'] = ('A', True, False)  
node['parent'] = parent_node #<-another node object  
node['action'] = 'Clean'  
node['g'] = parent_node['g']+clean_cost
```

Generic Search Algorithm

```
Initialize 'current' node to start state
Initialize 'closed' as an empty list
Initialize 'open' as one of (stack, queue, priority queue)
while not( current['state'] is goal state):
    Add current['state'] to closed
    successors = successors of current['state']
    for s in successors:
        if not(s.state is in closed):
            Add new node for state to open
    current = next node in open that's not in closed
path = list()
while current has a parent:
    Add current['action'] to the front of path
    current = current['parent']
return path
```

Generic Search Algorithm - notes

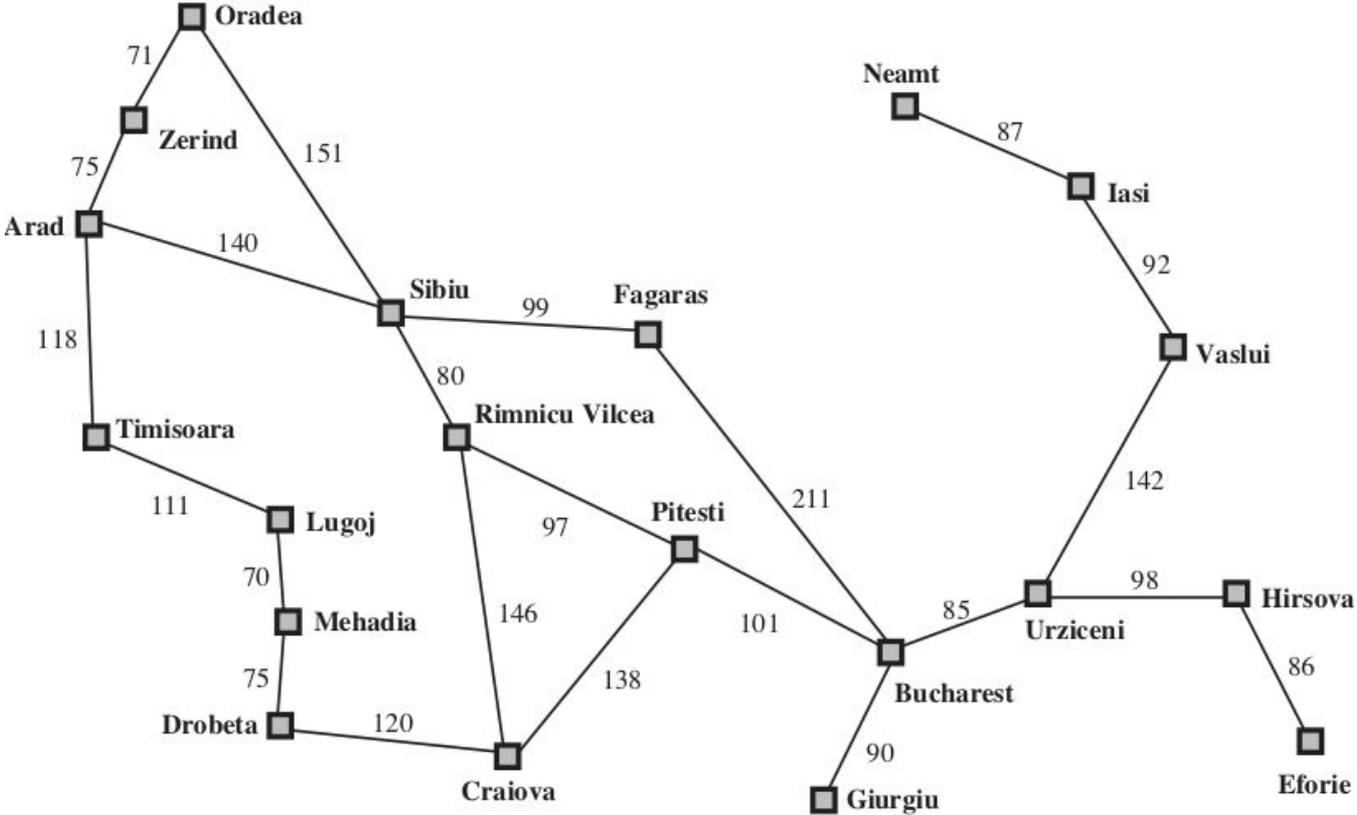
Can implement BFS, DFS, or UCS by picking the right data structure for `open`

- DFS: stack
- BFS: queue
- UCS: priority queue, with priority being `node['g']`

This version is similar to the Graph-Search algorithm (Fig 3.7) in the text, with some minor changes

```
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    Add current['state'] to closed
    successors = successors of current['state']
    for s in successors:
        if not(s.state is in closed):
            Add new node for state to open
    current = next node in open
path = list()
while current has a parent:
    Add current['action'] to the front of path
    current = current['parent']
return path
```

Romania



Romania - DFS

Current: Arad

Open: [S,T,Z]

Closed: [A]

Current: Sibiu

Open: [F,O,R,T,Z]

Closed: [A,S]

Current: Fagaras

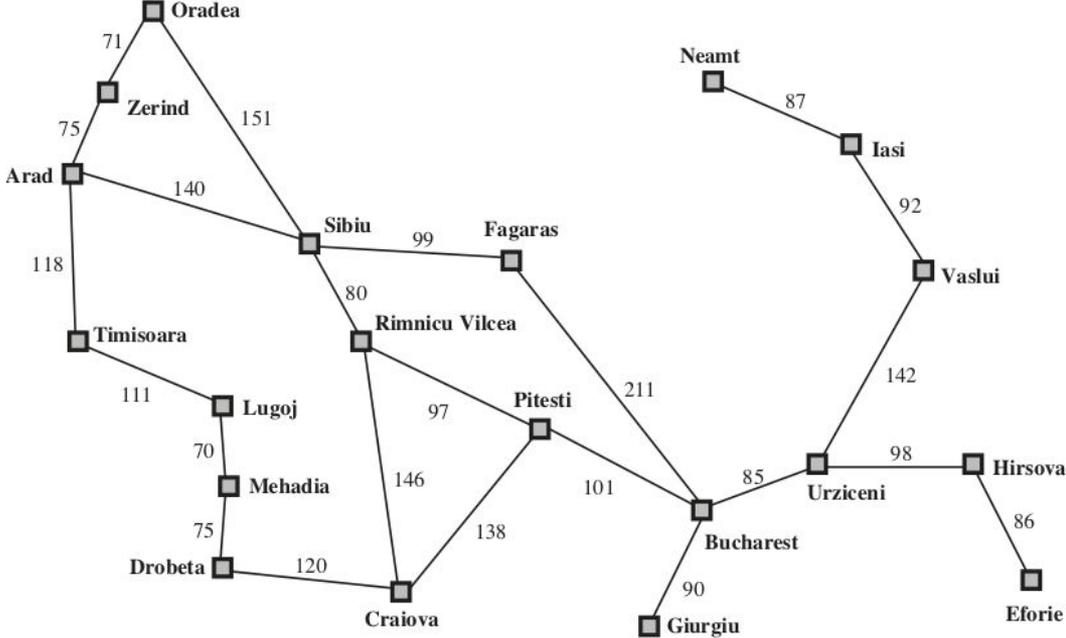
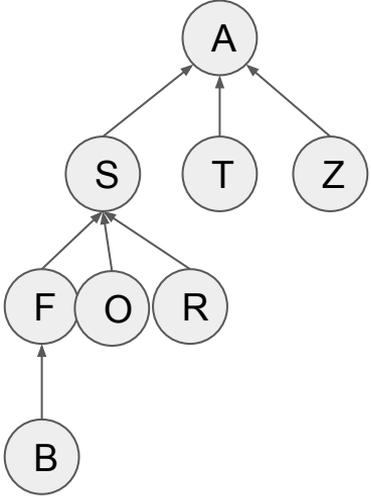
Open: [B,O,R,T,Z]

Closed: [A,S,F]

Current: Bucharest

Open: [O,R,T,Z]

Closed: [B,A,S,F]



Solution: [A->S, S->F, F->B]

Cost: 450

Romania - DFS (reversed alpha)

For DFS: Order of expansion can have a big impact on number of nodes explored, and the final path returned!

Arad
[Z,T,S]
[A]

Rimnicu Vilcea
[P,C,F,T,S]
[A,Z,O,S,R]

Zerind
[O,T,S]
[A,Z]

Pitesti
[C,B,C,F,T,S]
[A,Z,O,S,R,P]

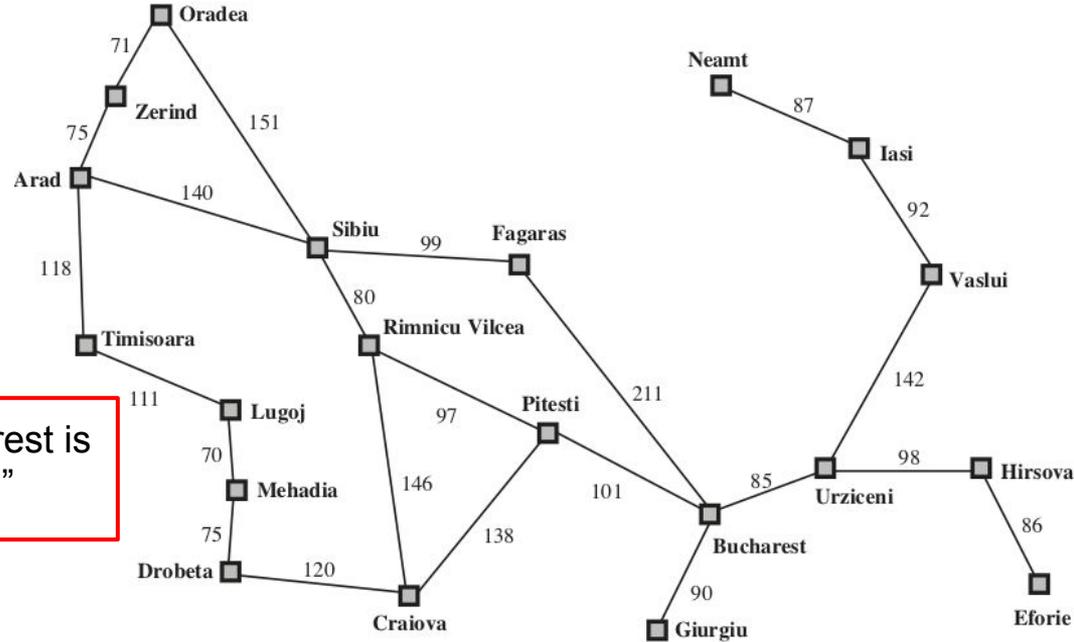
Oradea
[S,T,S]
[A,Z,O]

Craiova
[D,B,C,F,T,S]
[A,Z,O,S,R,P,C]

Sibiu
[R,F,T,S]
[A,Z,O,S]

Drobeta
[M,B,C,F,T,S]
[A,Z,O,S,R,P,C,D]

Bucharest is "buried"



Solution (eventually): [A->Z, Z->O, O->S, S->R, R->P, P->B]
Cost: 575

Romania - BFS

Arad
[S,T,Z]
[A]

Fagaras
[O,R,L,O,B]
[A,S,T,Z,F]

Sibiu
[T,Z,F,O,R]
[A,S]

Oradea
[R,L,O,B]
[A,S,T,Z,F,O]

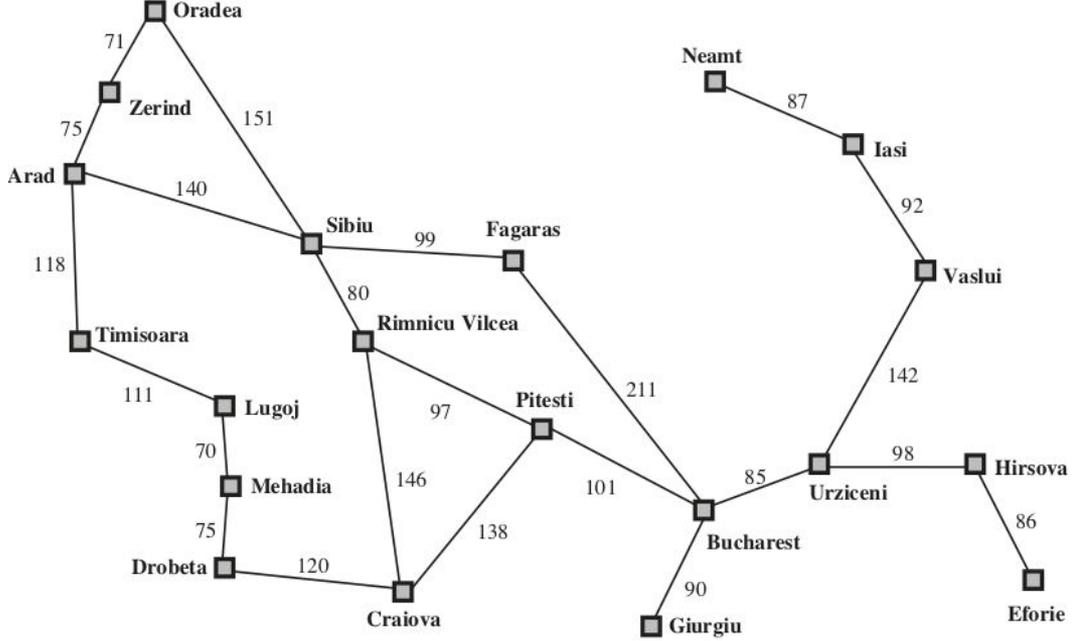
Timisoara
[Z,F,O,R,L]
[A,S,T]

Rimnicu Vilcea
[L,O,B,C,P]
[A,S,T,Z,F,O,R]

Zerind
[F,O,R,L,O]
[A,S,T,Z]

Lugoj
[O,B,C,P,M]
[A,S,T,Z,F,O,R,L]

Bucharest
[C,P,M,G,U]
[A,S,T,Z,F,R,L,O,B]



Solution: [A->S, S->F, F->B]
Cost: 450

Romania - UCS

Arad (0)

[Z(75), T(118), S(140)]

[A]

Zerind (75)

[T(118), S(140), O(146)]

[A,Z]

Timisoara (118)

[S(140), O(146), L(229)]

[A,Z,T]

Sibiu (140)

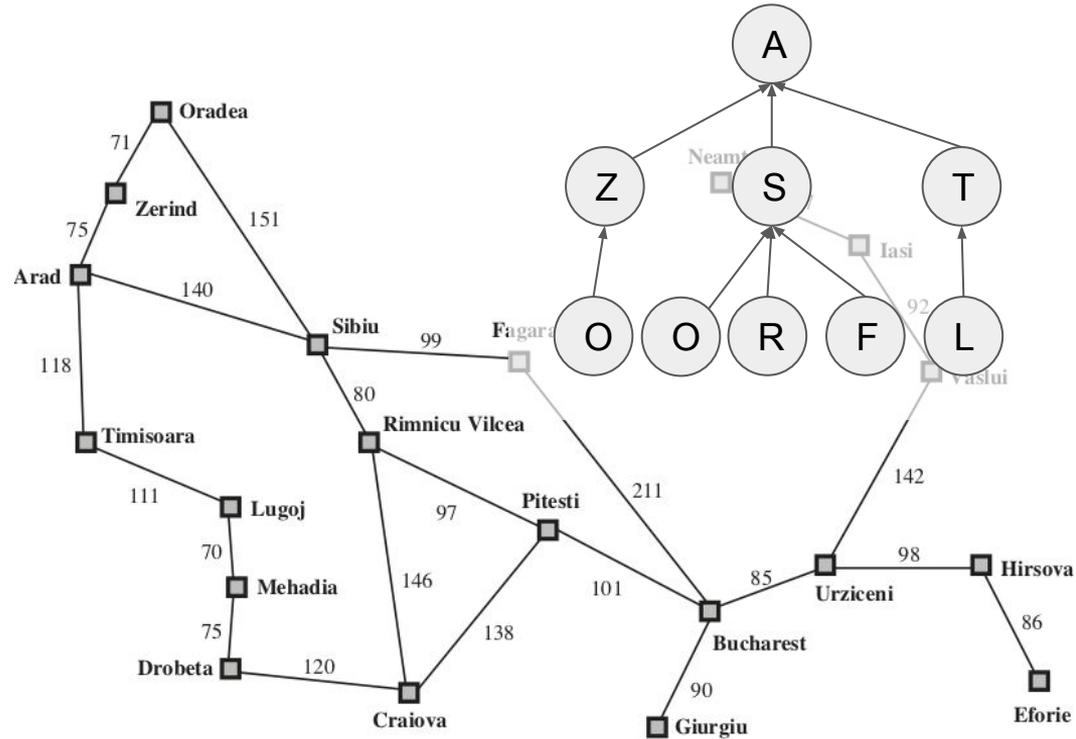
[O(146),R(220),L(229),F(239),O(291)]

[A,Z,T,S]

Oradea (146)

[R(220),L(229),F(239),O(291)]

[A,Z,T,S,O]



Romania - UCS

Rimnicu Vilcea (220)

[L(229),F(239),O(291),**P**(317),C(366)]

[A,Z,T,S,O,R]

Lugoj(229)

[F(239),O(291),**M**(299),P(317),C(366)]

[A,Z,T,S,O,R,L]

Fagaras(239)

[O(291),M(299),P(317),C(366),**B**(450)]

[A,Z,T,S,O,R,L,F]

Mehadia(299)

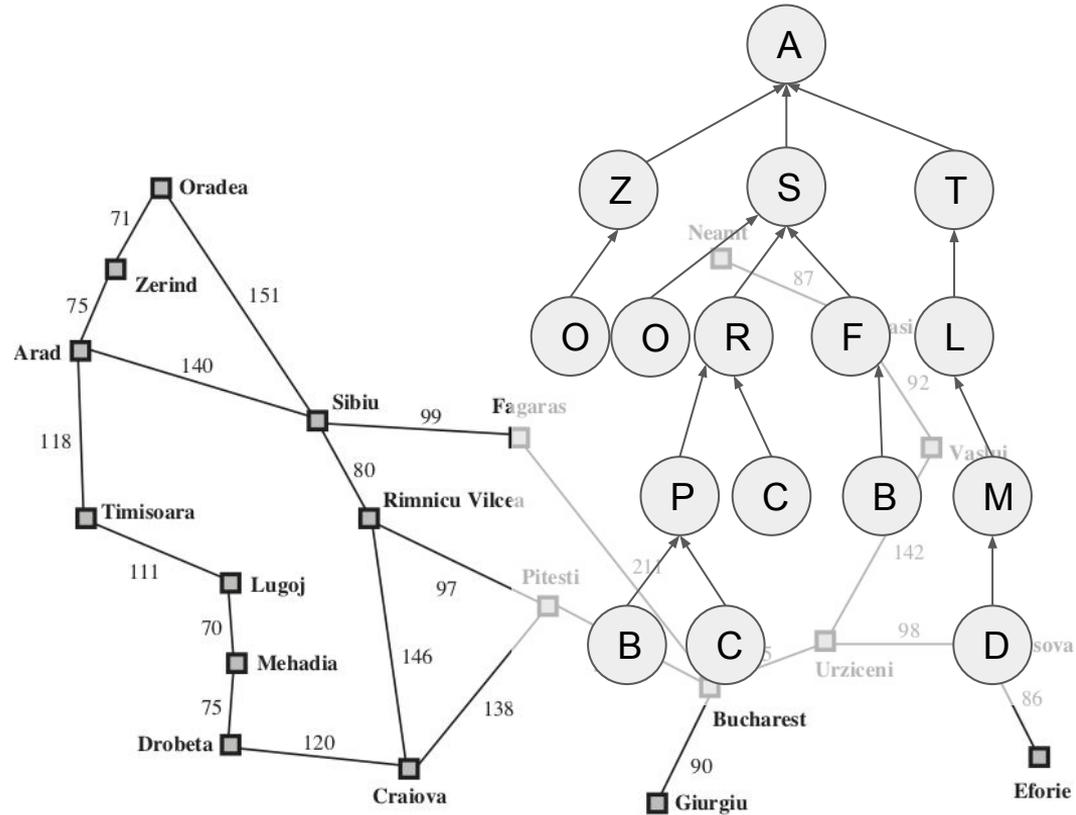
[P(317),C(366),**D**(374),B(450)]

[A,Z,T,S,O,R,L,F,M]

Pitesti(317)

[C(366),D(374),**B**(418),B(450),C(455)]

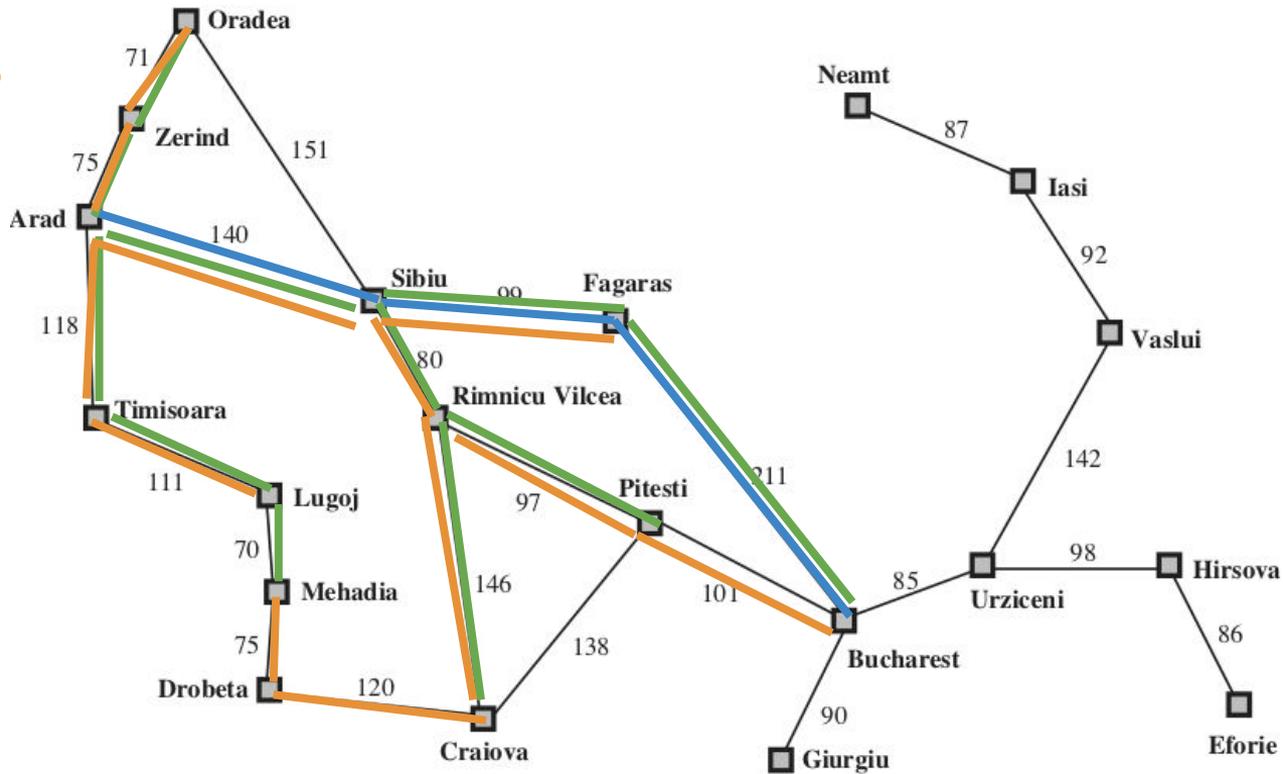
[A,Z,T,S,O,R,L,F,M,P]



Comparing DFS, BFS, and UCS

- DFS was highly dependent on the order that child nodes were explored
- BFS took more iterations than DFS, but less than UCS and DFS-reverse-alpha
- DFS and BFS both found the same (sub-optimal solution)
- UCS found the best solution, but took as long as DFS-reverse-alpha

How can we improve?



Uninformed vs Informed Search

Uninformed Search

- Does not use any domain specific knowledge
- Only looks at **edges** and **edge costs**, the problem is completely abstract
- We can find the optimal path (UCS) but it might take a long time to compute

Informed Search

- Formally represent domain knowledge that can **guide** the search in “good” directions
- Leverage the optimality and completeness guarantees from UCS if possible

A* Search preview

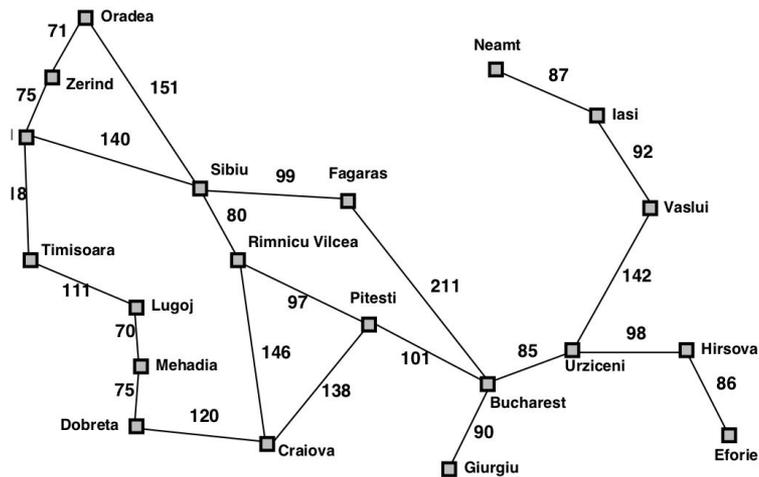
Something like UCS, but with a little “hint” about the right direction to go

Priority queue with priority
 $f(s) = g(s) + h(s)$

$h(s)$: “Heuristic” function, that estimates the cost-to-go from s

Note: $h(s)$ should be easier to compute than solving the original problem!

Romania with step costs in km



Straight-line distance to Bucharest

Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	176
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	100
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374

Summary and preview

Wrapping up

- We can implement DFS, BFS, and UCS with a **single algorithm**, and choose the behavior we want by picking the appropriate data structure
- Examples of applying search

For next time

- A* Search
- Admissibility, Consistency, and Optimality