Generic Search Algorithm and examples

CS 480
Intro to Artificial Intelligence

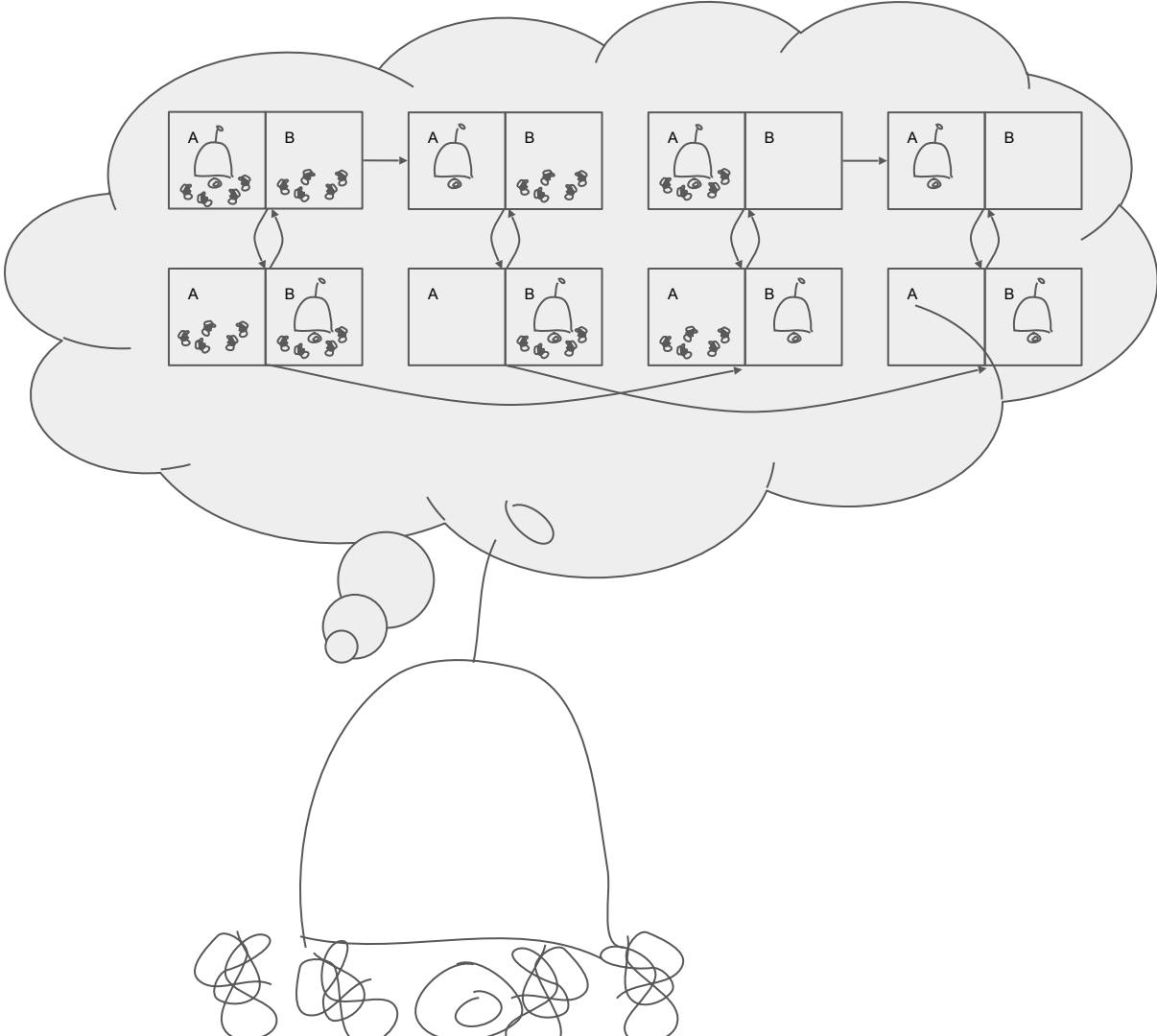
Recall

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

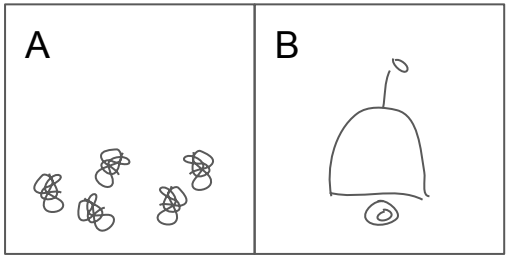
- Depth First Search
- Breadth First Search
- Uniform Cost Search

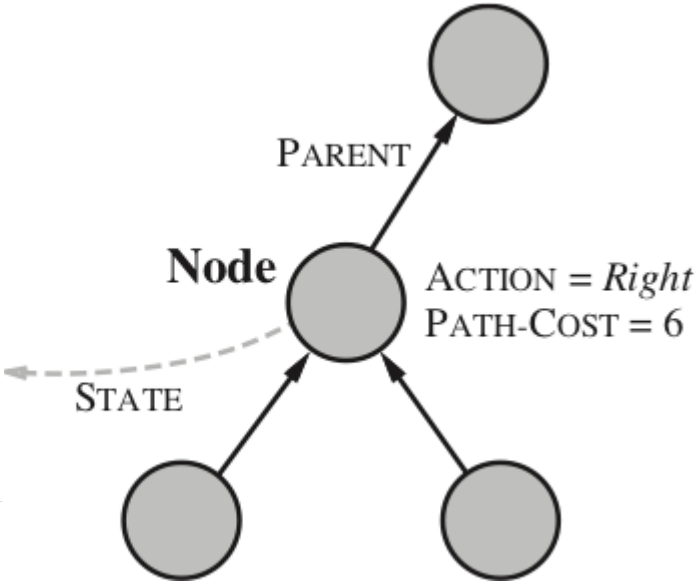


Search Node data structure

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**





'loc' 'A-clean' 'B-clean'

```
node=dict()
node['state'] = ('B', False, True)
node['parent'] = parent_node #<-another node object
node['action'] = 'Right'
node['g'] = parent_node['g']+action_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

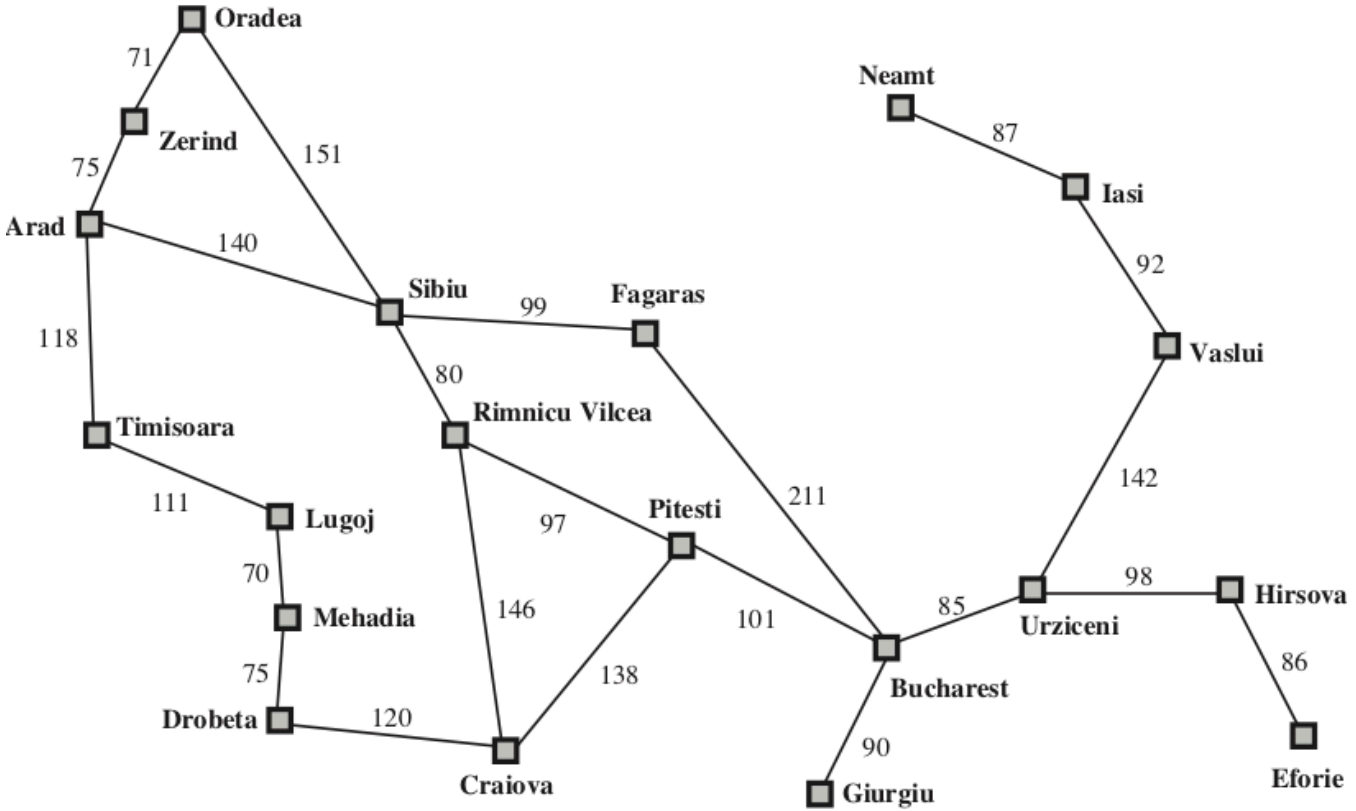
Can implement BFS, DFS, or UCS by picking the right data structure for `open`

- 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

```
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
path = list()
while current has a parent:
            Add current['action'] to the front of path
            current = current['parent']
return path
```

Romania


Oradea
71
Zerind
75
151
Arad
140
Sibiu
99
Fagaras
118
80
Rimnicu Vilcea
Timisoara
111
Lugoj
97
Pitesti
211
70
Mehadia
146
101
75
138
Drobeta
120
Craiova
Bucharest
90
Giurgiu
Neamt
87
Iasi
92
Vaslui
142
98
Hirsova
85
Urziceni
86
Eforie

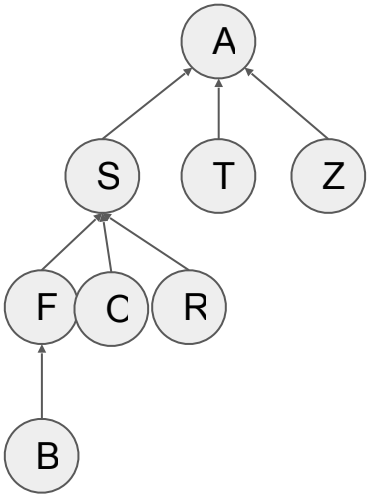
Romania - DFS

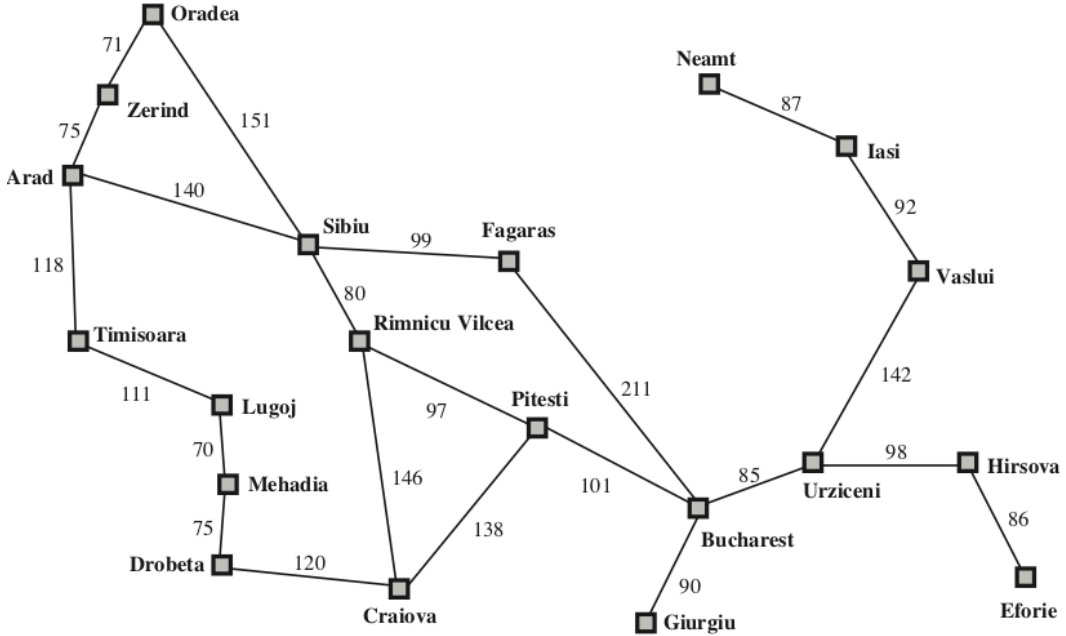
Current: Arad
Open: [**S,T,Z**]
Closed: [A]

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]





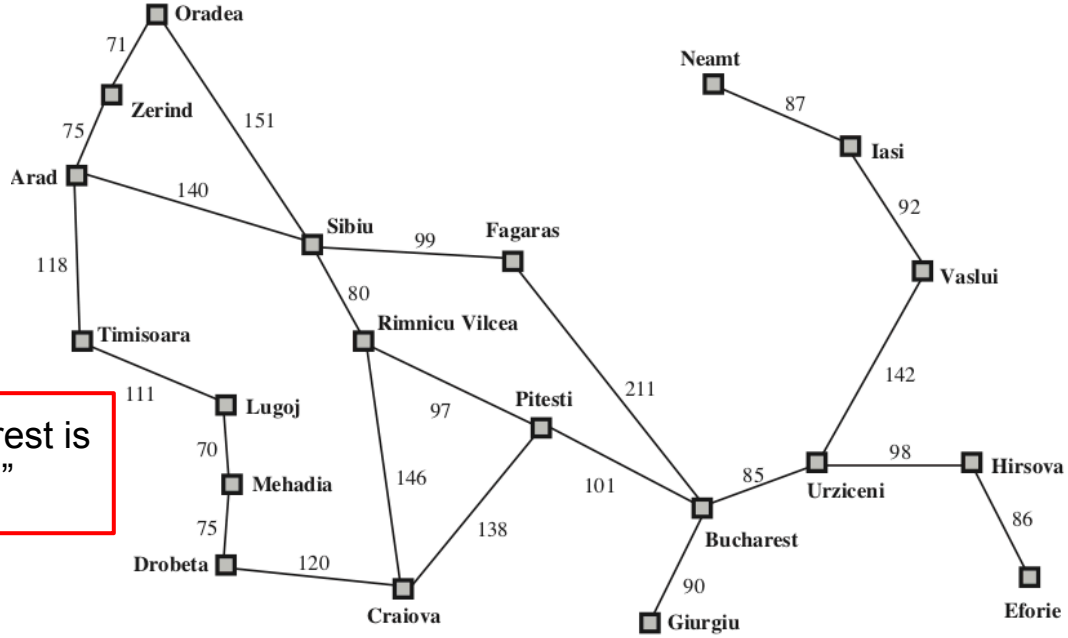
Solution: [A->S, S->F, F->B]
Cost: 450

Romania - DFS (reversed order)

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

Arad	Rimnicu Vilcea
[**Z,T,S**]	[**P**,**C**,F,T,S]
[A]	[A,Z,O,S,R]
Zerind	Pitesti
[**O**,T,S]	[**C**,**B**,C,F,T,S]
[A,Z]	[A,Z,O,S,R,P]
Oradea	Craiova
[**S**,T,S]	[**D**,B,C,F,T,S]
[A,Z,O]	[A,Z,O,S,R,P,C]
Sibiu	Drobeta
[**R**,**F**,T,S]	[**M**,B,C,F,T,S]
[A,Z,O,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]

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

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

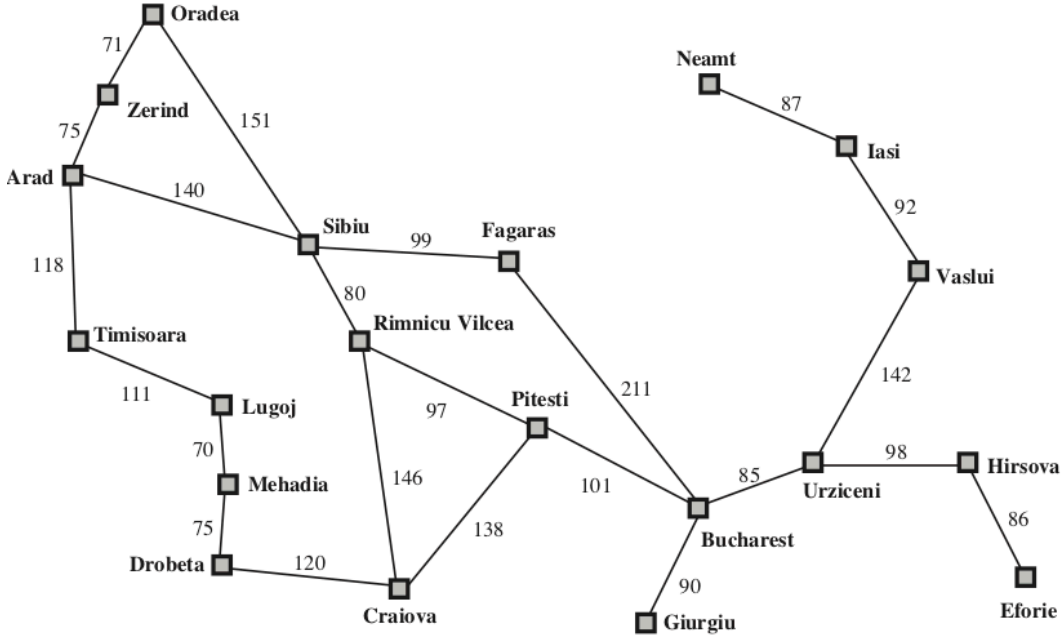
Zerind
[F,O,R,L,**O**]
[A,S,T,Z]

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

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

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

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

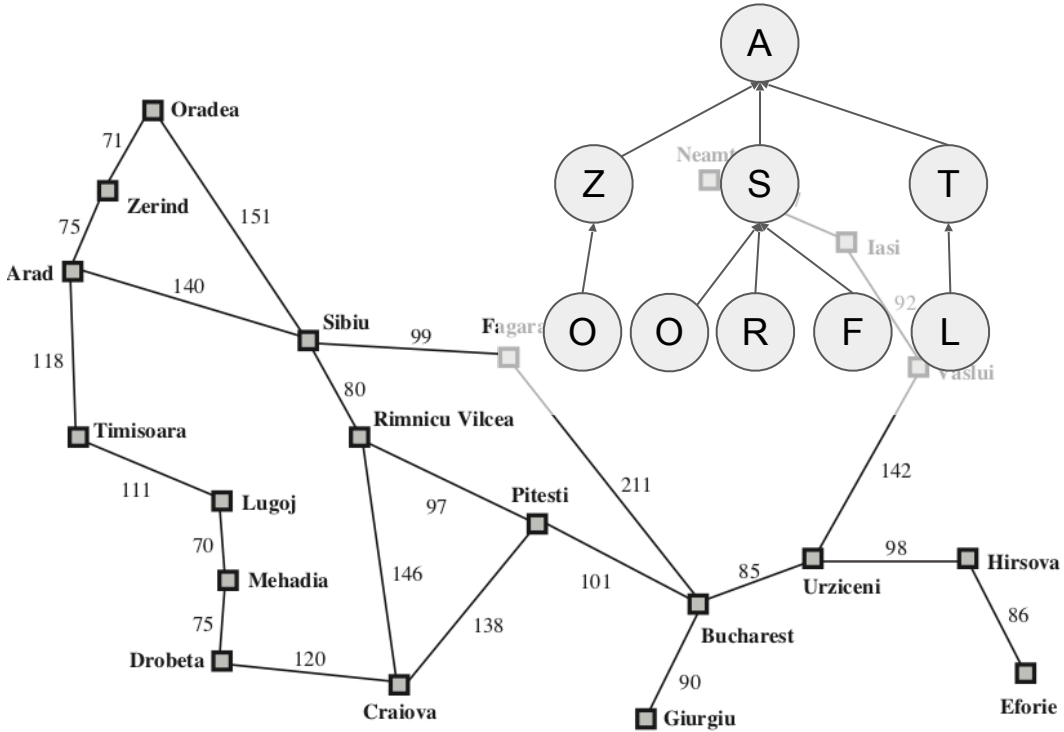
Arad (0)
[**Z**(75), **T**(118), **S**(140)]
[A]

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

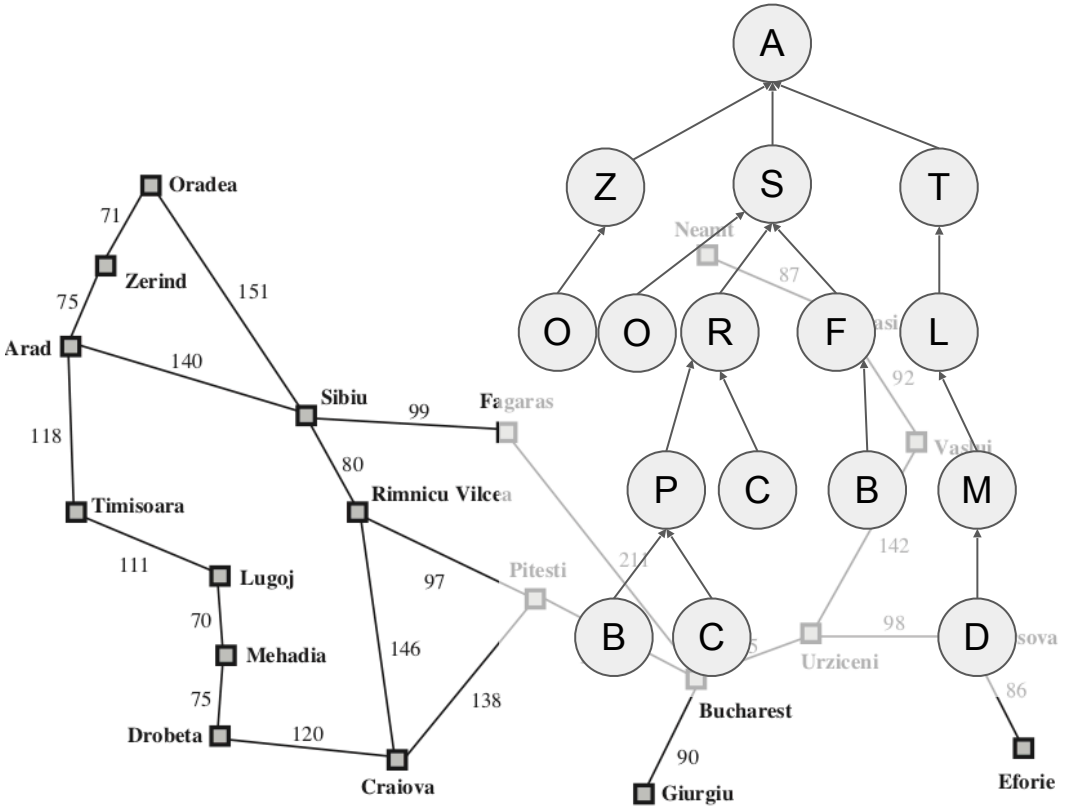
Rimnicu Vilcea (220)
[L(229),F(239),O(291),**P**(317),**C**(366)]
[A,Z,T,S,O,R]

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]

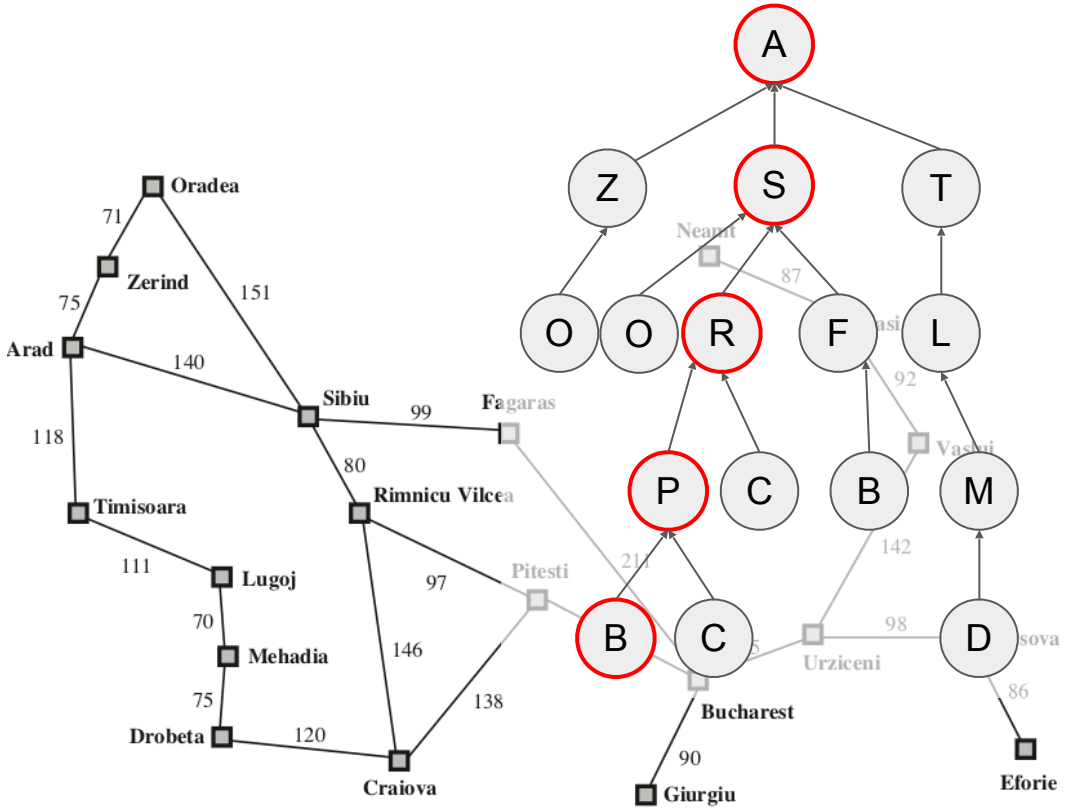


Romania - UCS

Craiova(366)
[D(374),B(418),B(450),C(455),**D**(486)]
[A,Z,T,S,O,R,L,F,M,P,C]

Drobeta(374)
[B(418),B(450),C(455),D(486)]
[A,Z,T,S,O,R,L,F,M,P,C,D]

Bucharest(418)
[B(450),C(455),D(486)]
[A,Z,T,S,O,R,L,F,M,P,C,D]

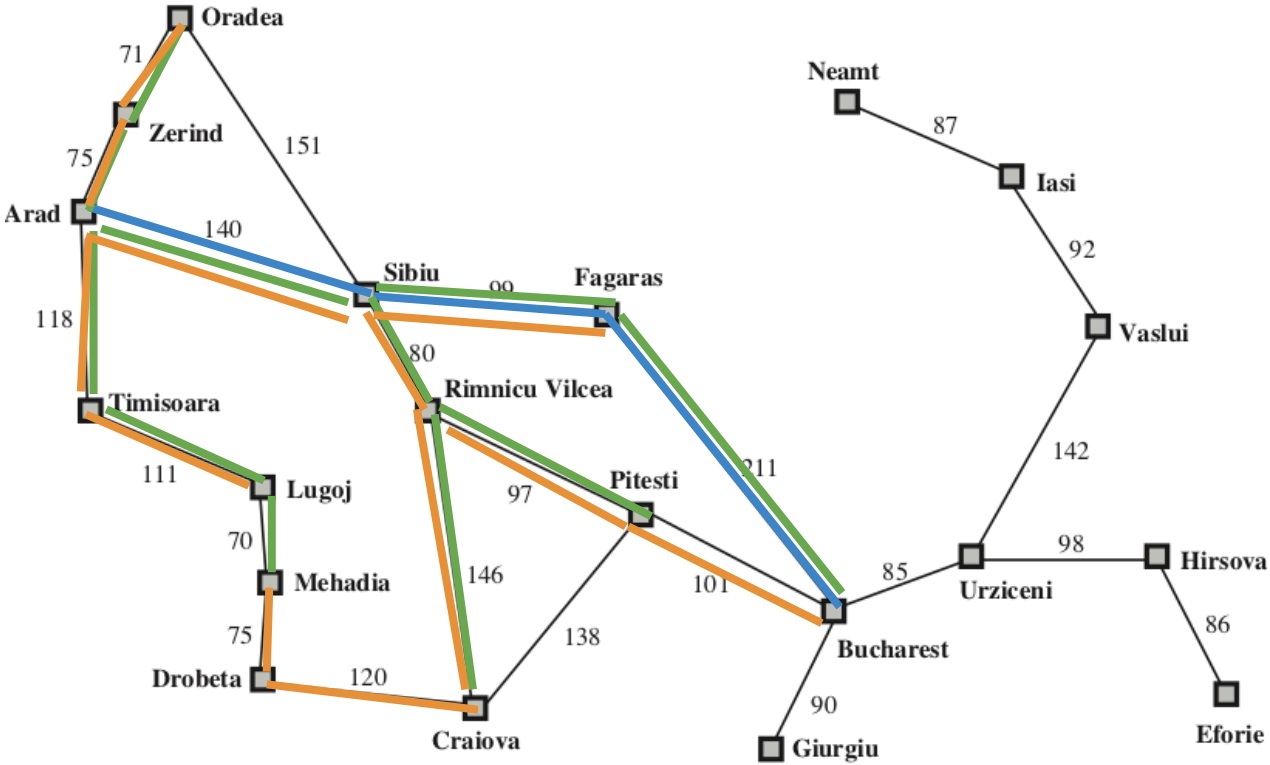


Solution: [A->S, S->R, R->P, P->B]
Cost: 418

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-order
- DFS and BFS both found the same (sub-optimal solution)
- UCS found the best solution, but took as long as DFS-reverse-order

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

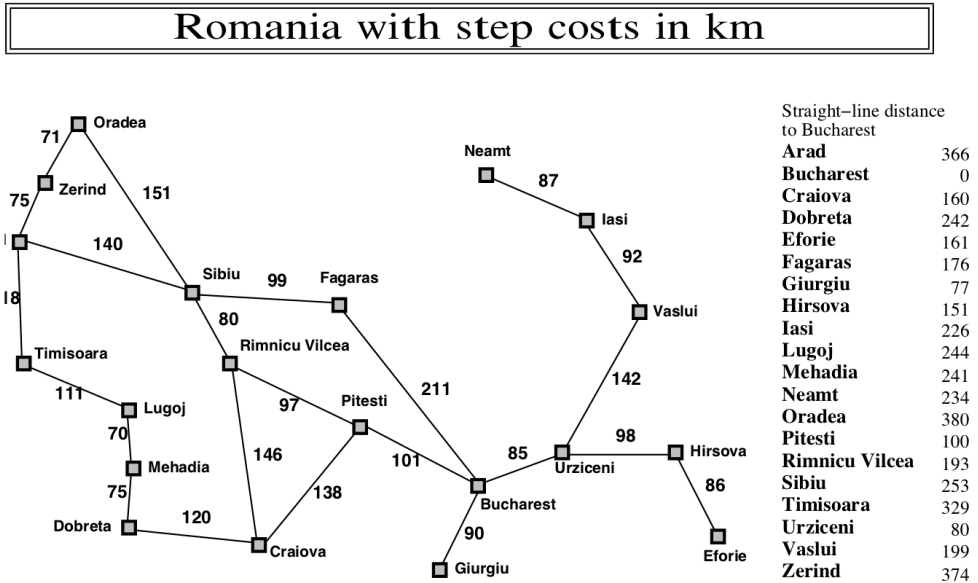
A* Search preview

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!



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