Artificial Intelligence

Lecture 02 - Search

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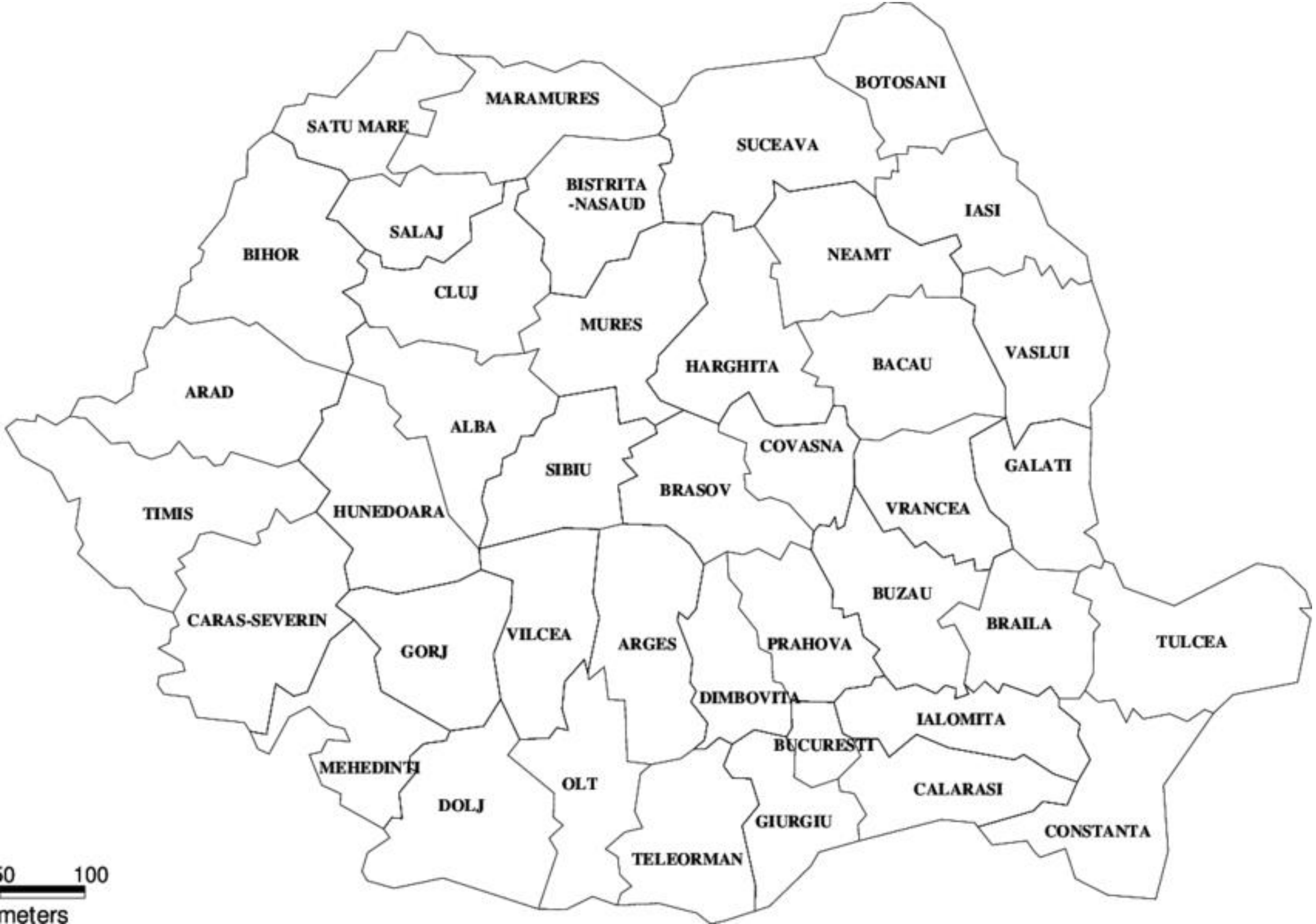
Searching – Problems and Solutions



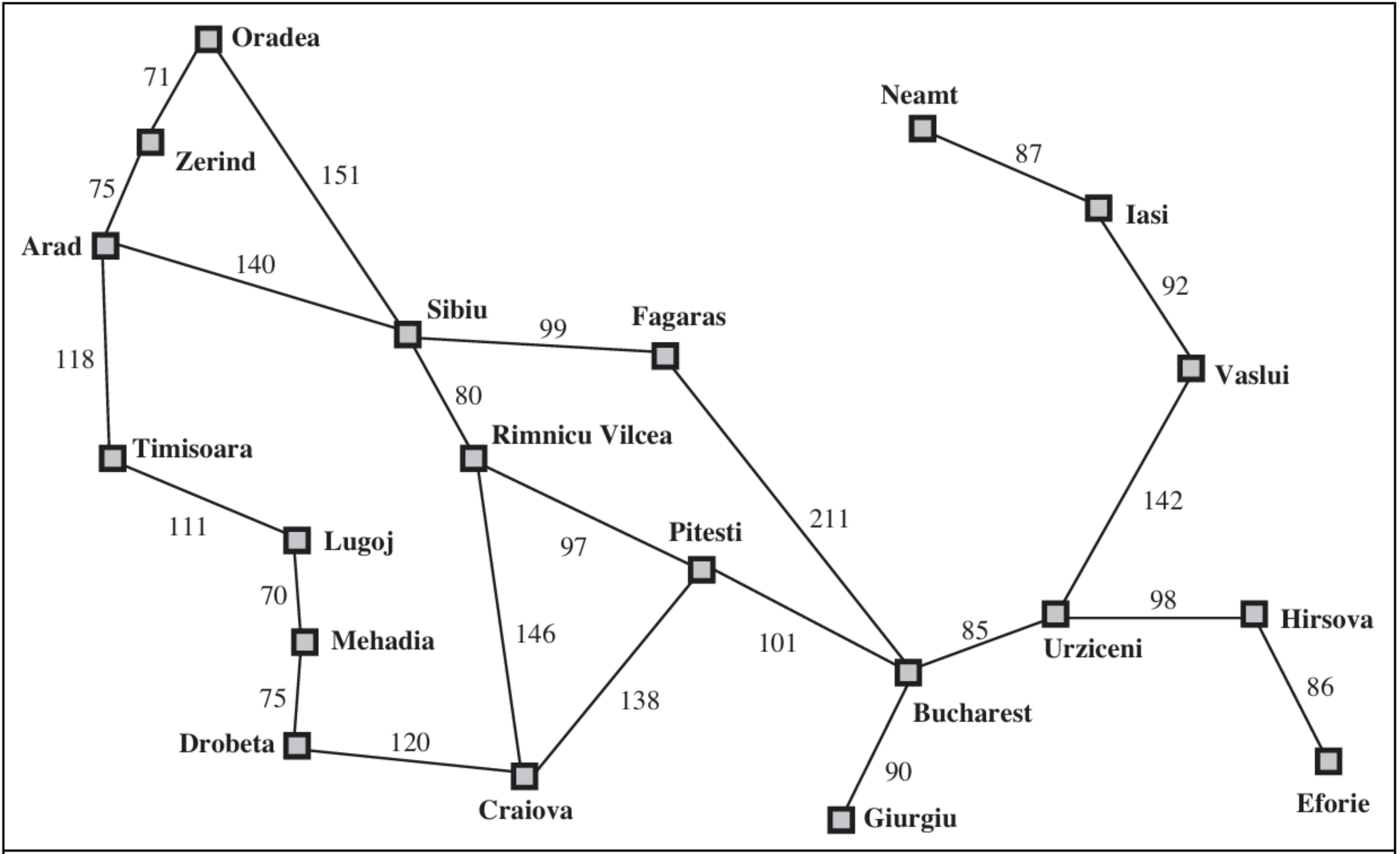
Searching – Problems and Solutions

BOTOSANI
MARAMURES
SATU MARE
SUCEAVA
BISTRITA
-NASAUD
IASI
SALAJ
BIHOR
NEAMT
CLUJ
MURES
VASLUI
HARGHITA
BACAU
ARAD
ALBA
COVASNA
SIBIU
GALATI
BRASOV
TIMIS
HUNEDOARA
VRANCEA
BUZAU
BRAILA
CARAS-SEVERIN
VILCEA
ARGES
PRAHOVA
TULCEA
GORJ
DIMBOVITA
IALOMITA
BUCURESTI
MEHEDINTI
OLT
CALARASI
DOLJ
GIURGIU
CONSTANTA
TELEORMAN
50
100
meters

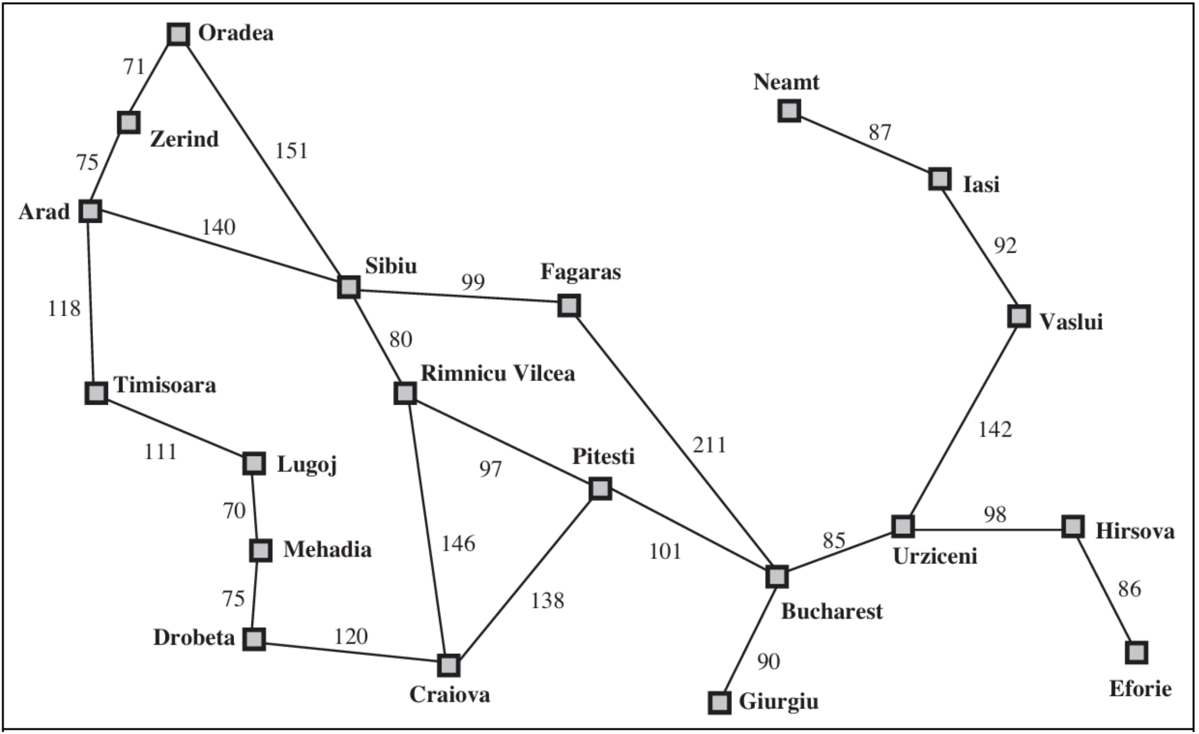
- Initial State
- Possible Actions
- Transition Model

This forms the state space which is a graph.

Searching – Romania Map

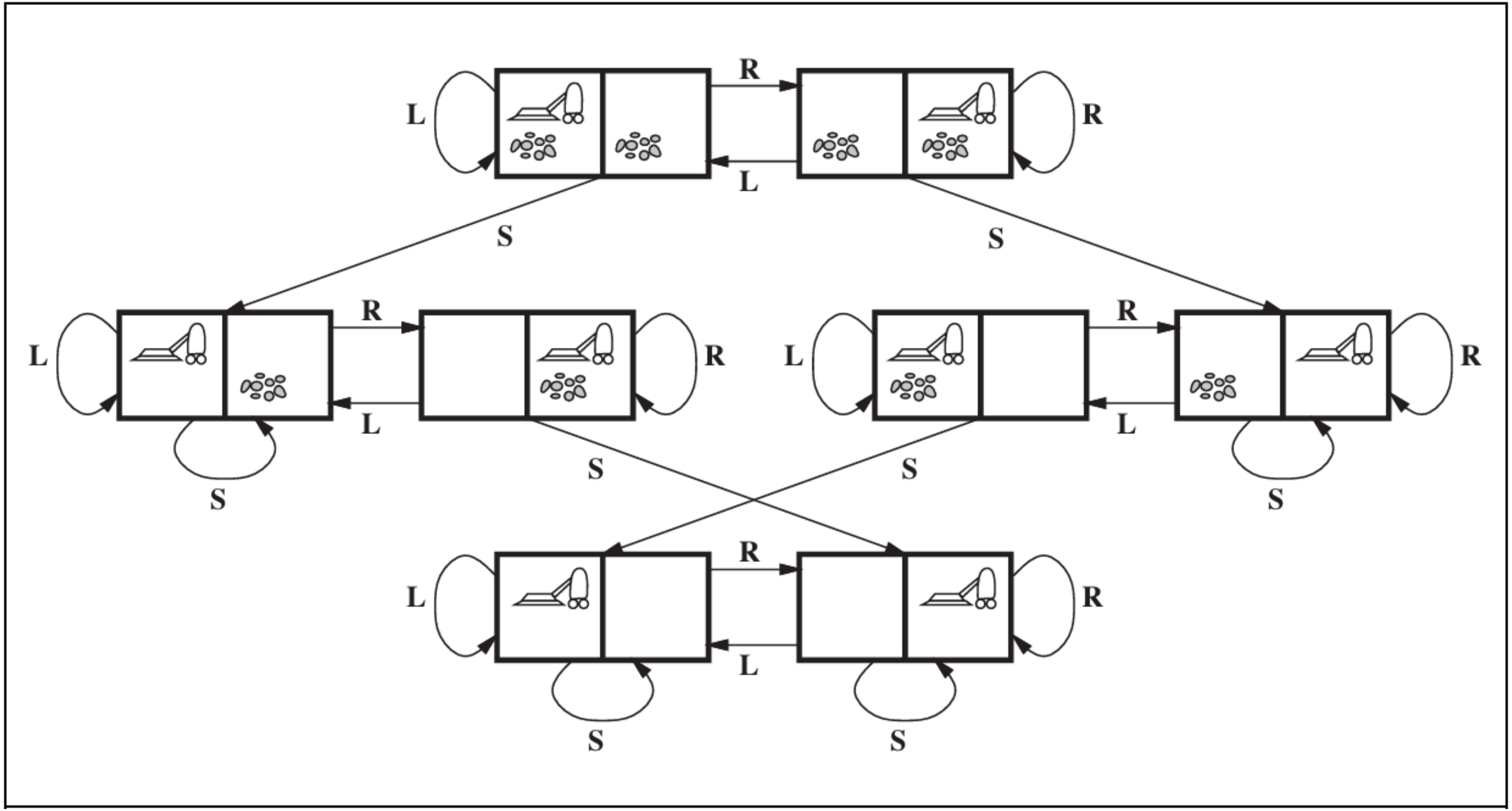


Searching – Romania Map



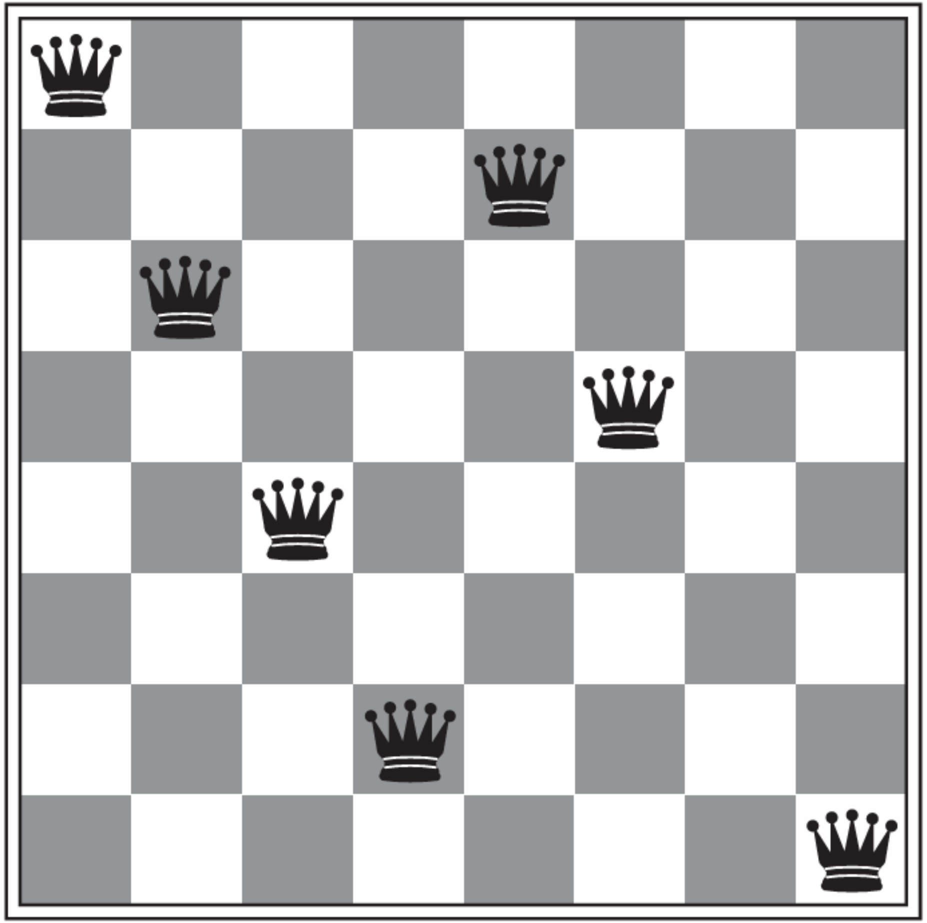
- Initial State: **in(A)**
- Possible Actions: **in(A)** has actions **{go(S), go(T), go(Z)}**
- Transition Model: **Result (in(A), go(Z)) = in(Z)**

Searching – States/Graph



- States: Consider Agent and Dirt Locations. $n2^n$ states.

Searching – States/Graph

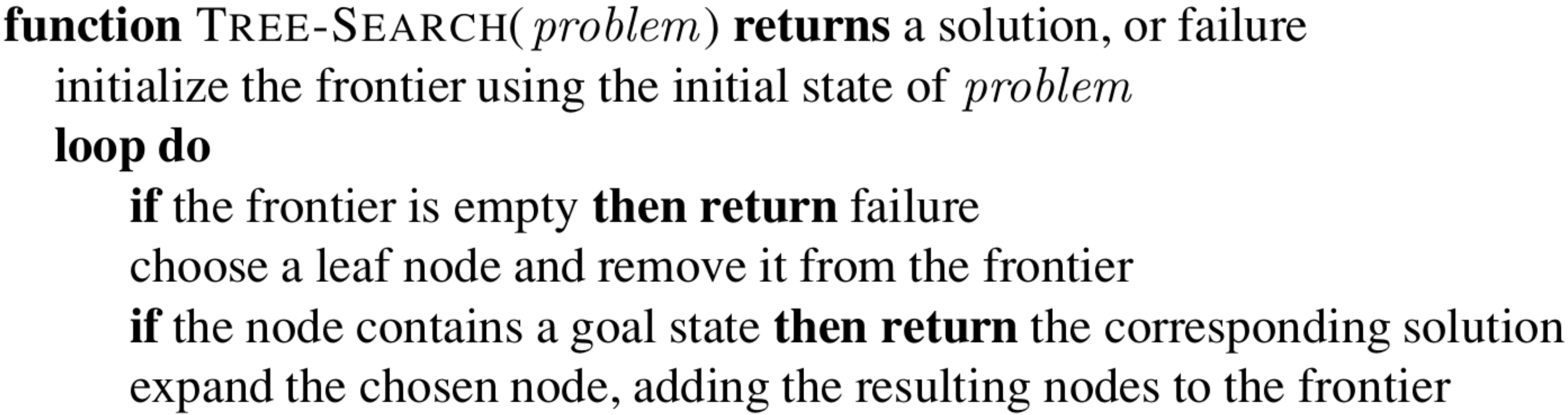


- Is this a goal state?

Searching – Problems in Real World

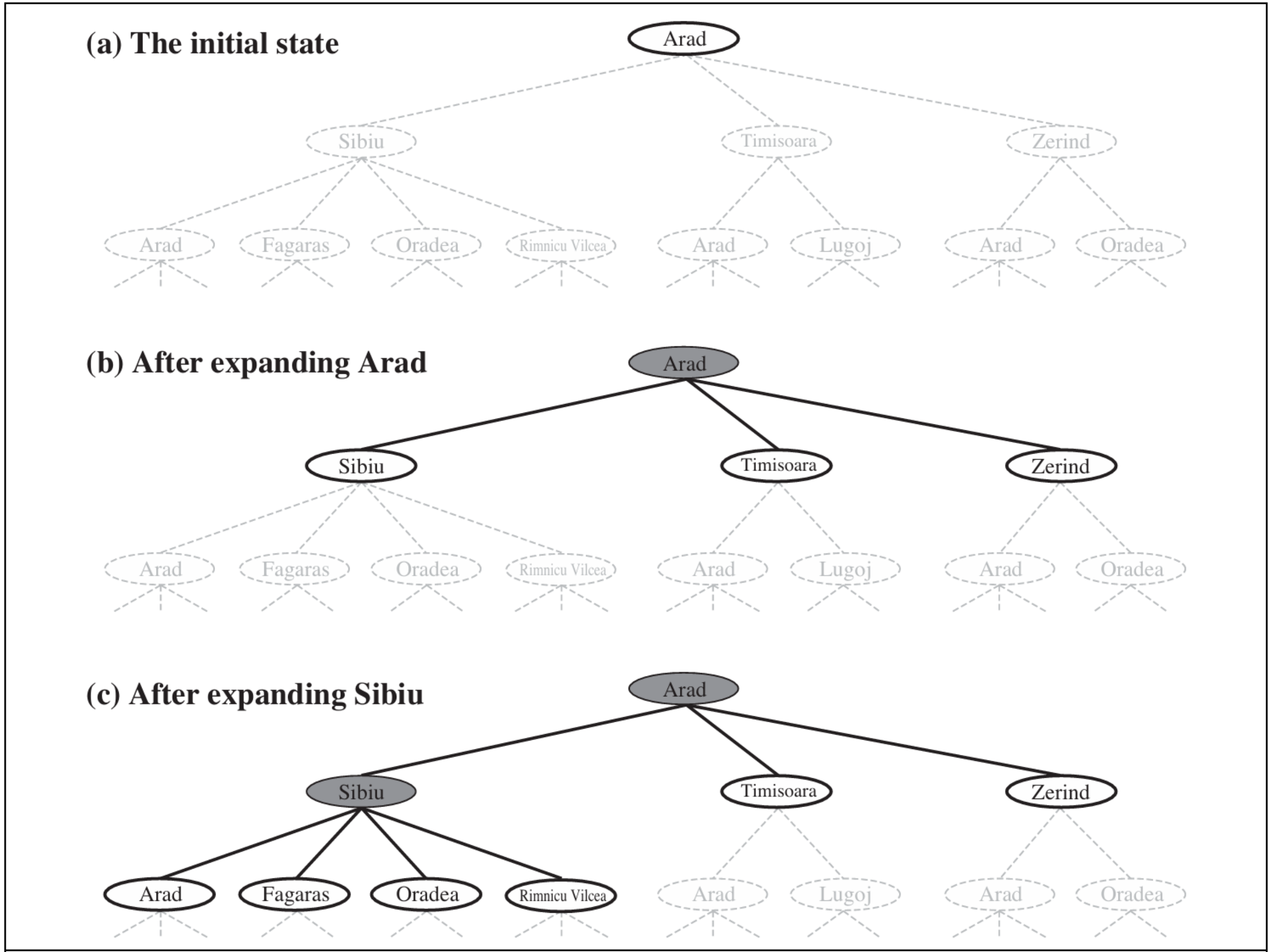
- States are much more complex
- Search Spaces can be huge
- NP-Hard (TSP)
- 2D/3D navigation

Searching – Finding a solution (Tree-Search)

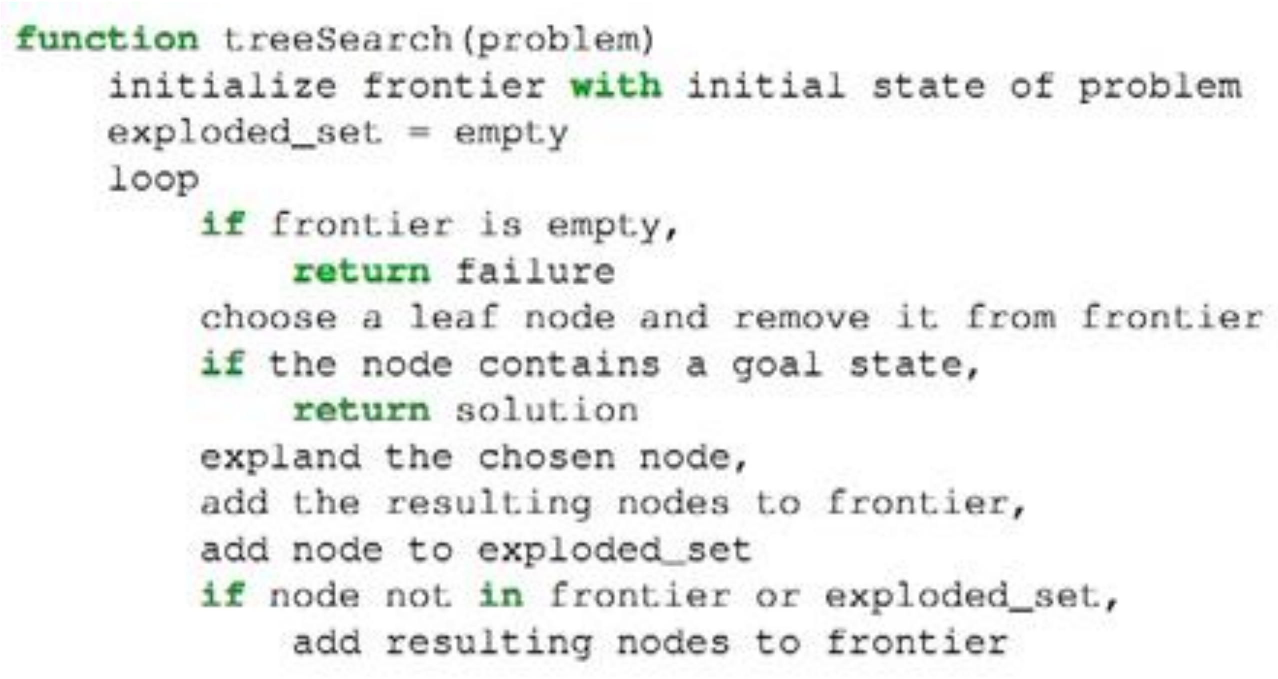


```
function TREE-SEARCH(problem) returns a solution, or failure
    initialize the frontier using the initial state of problem
    loop do
        if the frontier is empty then return failure
        choose a leaf node and remove it from the frontier
        if the node contains a goal state then return the corresponding solution
        expand the chosen node, adding the resulting nodes to the frontier
```

Searching – Expanding Trees

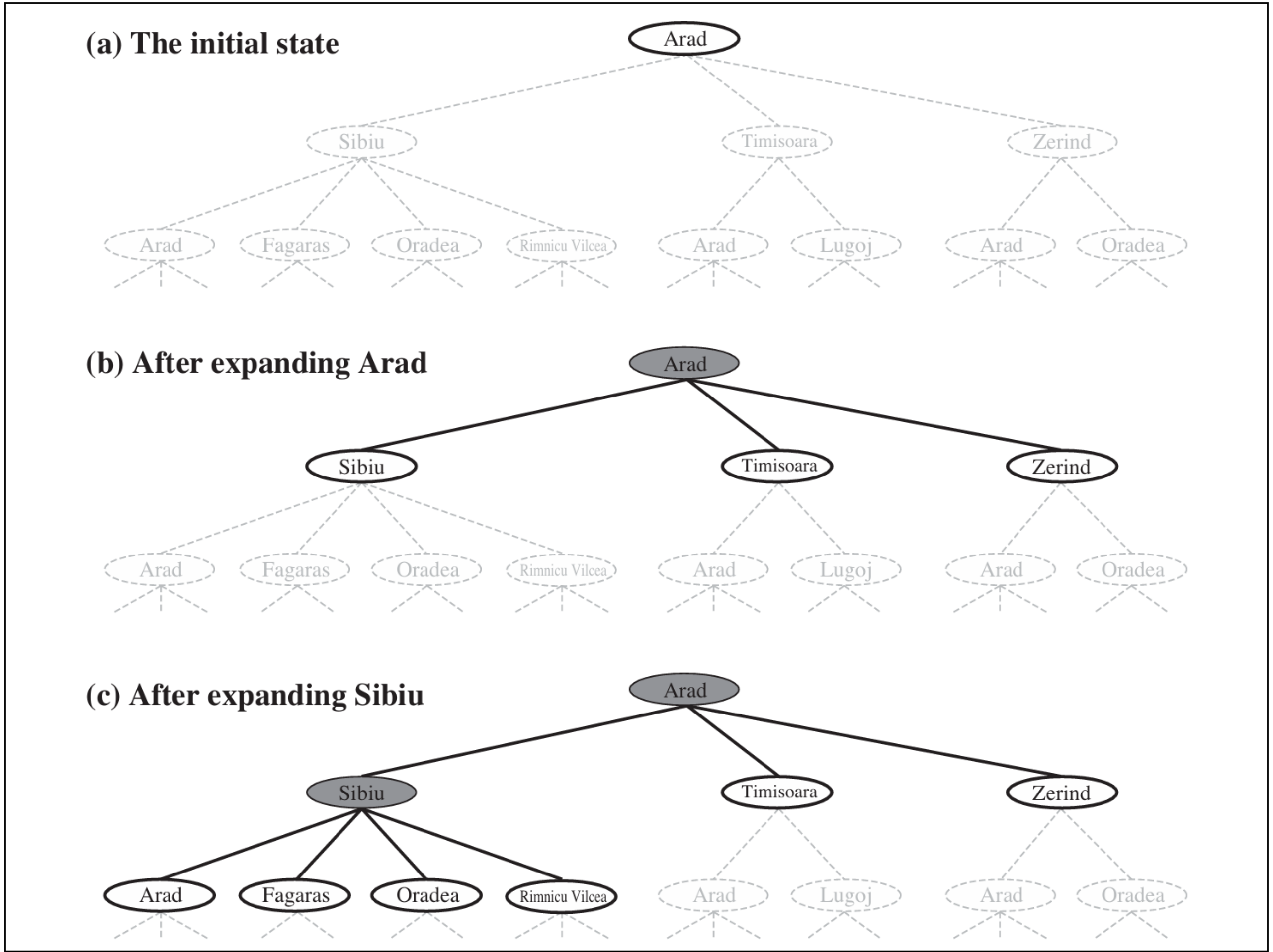


Searching – Expand but ignore loops

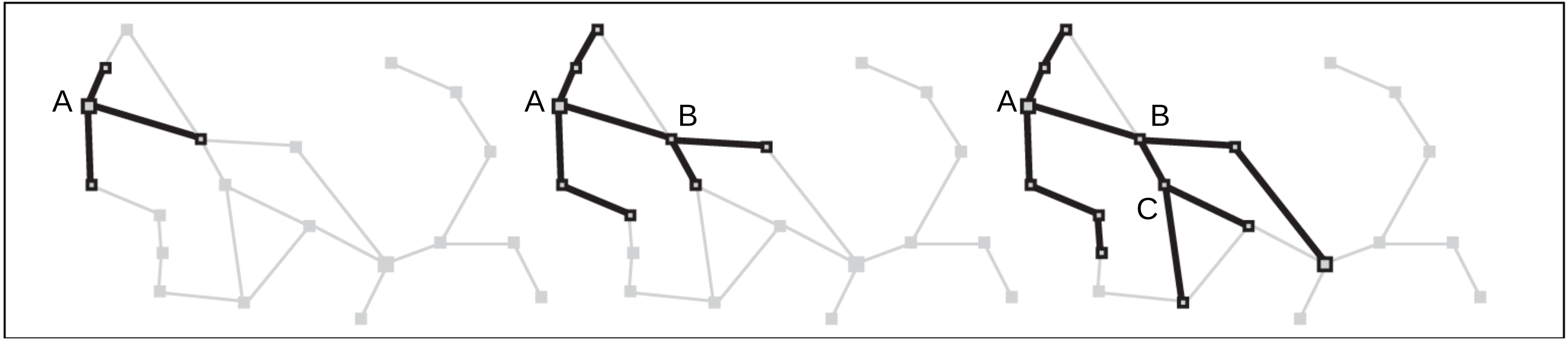


```
function treeSearch(problem)
    initialize frontier with initial state of problem
    exploded_set = empty
    loop
        if frontier is empty,
            return failure
        choose a leaf node and remove it from frontier
        if the node contains a goal state,
            return solution
        expland the chosen node,
        add the resulting nodes to frontier,
        add node to exploded_set
        if node not in frontier or exploded_set,
            add resulting nodes to frontier
```

Searching – Expanding Trees

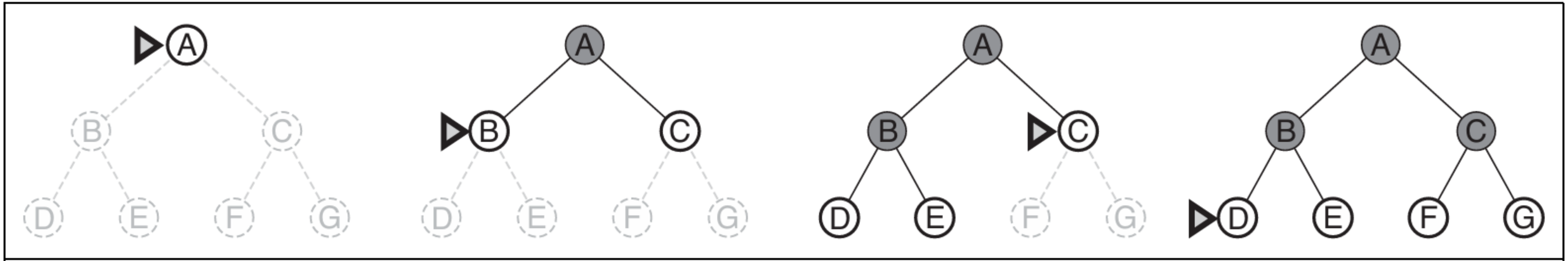


Searching – Expanding Trees

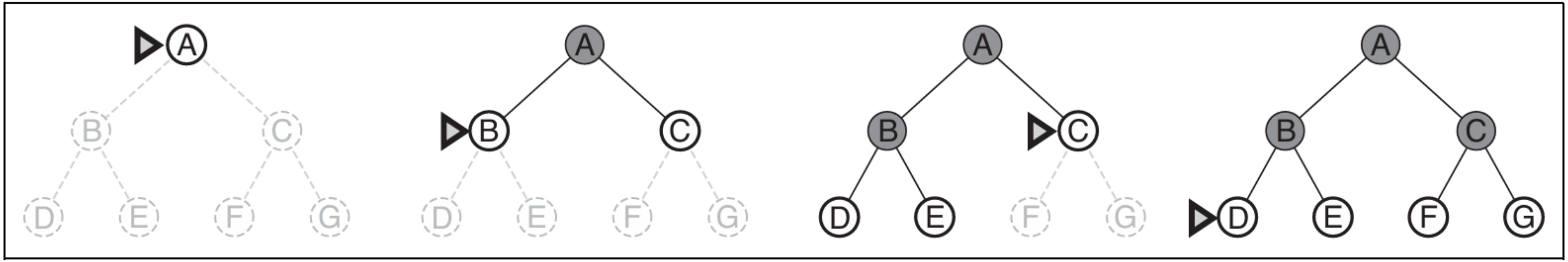


Uninformed Search – Breadth First Search (BFS)

```
function BREADTH-FIRST-SEARCH(problem) returns a solution, or failure
  node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
  if problem.GOAL-TEST(node.STATE) then return SOLUTION(node)
  frontier ← a FIFO queue with node as the only element
  explored ← an empty set
  loop do
     if EMPTY?(frontier) then return failure
     node ← POP(frontier)   /* chooses the shallowest node in frontier */
     add node.STATE to explored
     for each action in problem.ACTIONS(node.STATE) do
        child ← CHILD-NODE(problem, node, action)
        if child.STATE is not in explored or frontier then
           if problem.GOAL-TEST(child.STATE) then return SOLUTION(child)
           frontier ← INSERT(child, frontier)
```

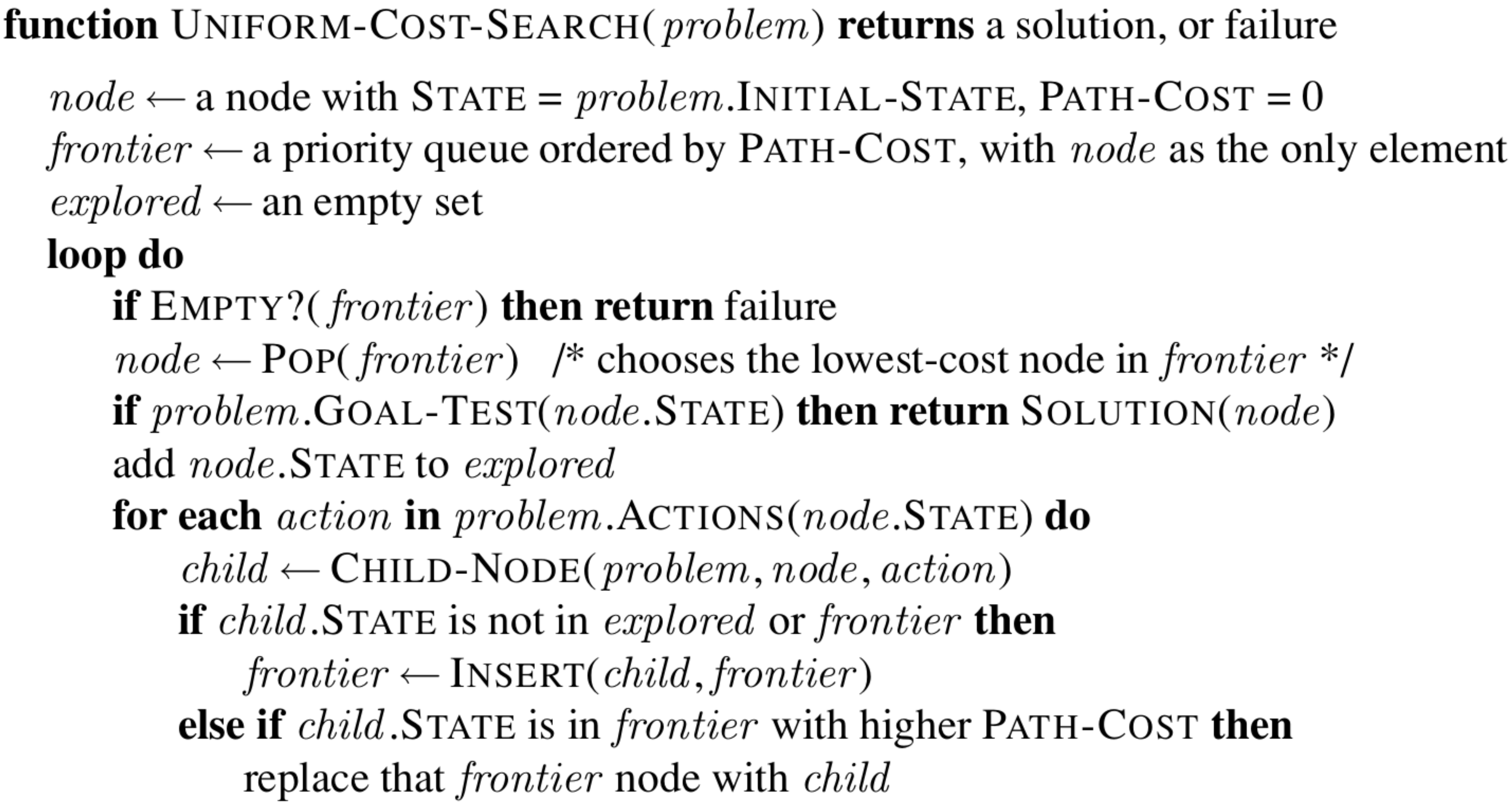


Breadth First Search



- If $\boldsymbol{b}$ is the branching factor
- $\boldsymbol{d}$ is the number of levels (depth) of the tree
- Time Complexity $\boldsymbol{O}(\boldsymbol{b}^{\boldsymbol{d}})$

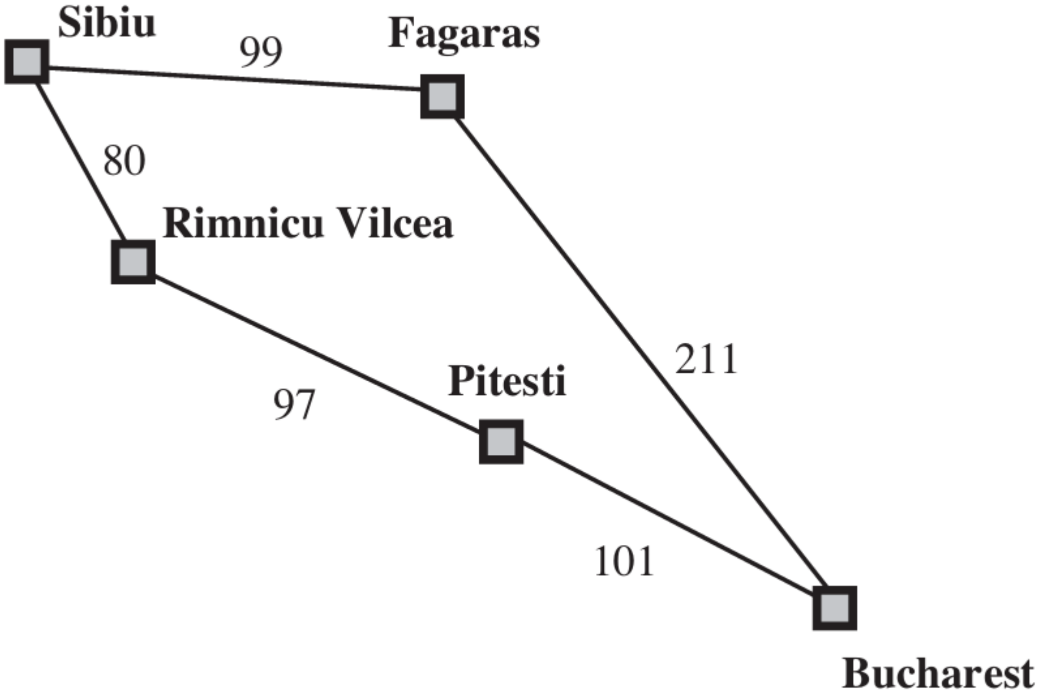
Searching – Uniform Cost Search (UCS)



```
function UNIFORM-COST-SEARCH(problem) returns a solution, or failure

  node ← a node with STATE = problem.INITIAL-STATE, PATH-COST = 0
  frontier ← a priority queue ordered by PATH-COST, with node as the only element
  explored ← an empty set
  loop do
      if EMPTY?(frontier) then return failure
      node ← POP(frontier)   /* chooses the lowest-cost node in frontier */
      if problem.GOAL-TEST(node.STATE) then return SOLUTION(node)
      add node.STATE to explored
      for each action in problem.ACTIONS(node.STATE) do
          child ← CHILD-NODE(problem, node, action)
          if child.STATE is not in explored or frontier then
              frontier ← INSERT(child, frontier)
          else if child.STATE is in frontier with higher PATH-COST then
              replace that frontier node with child
```

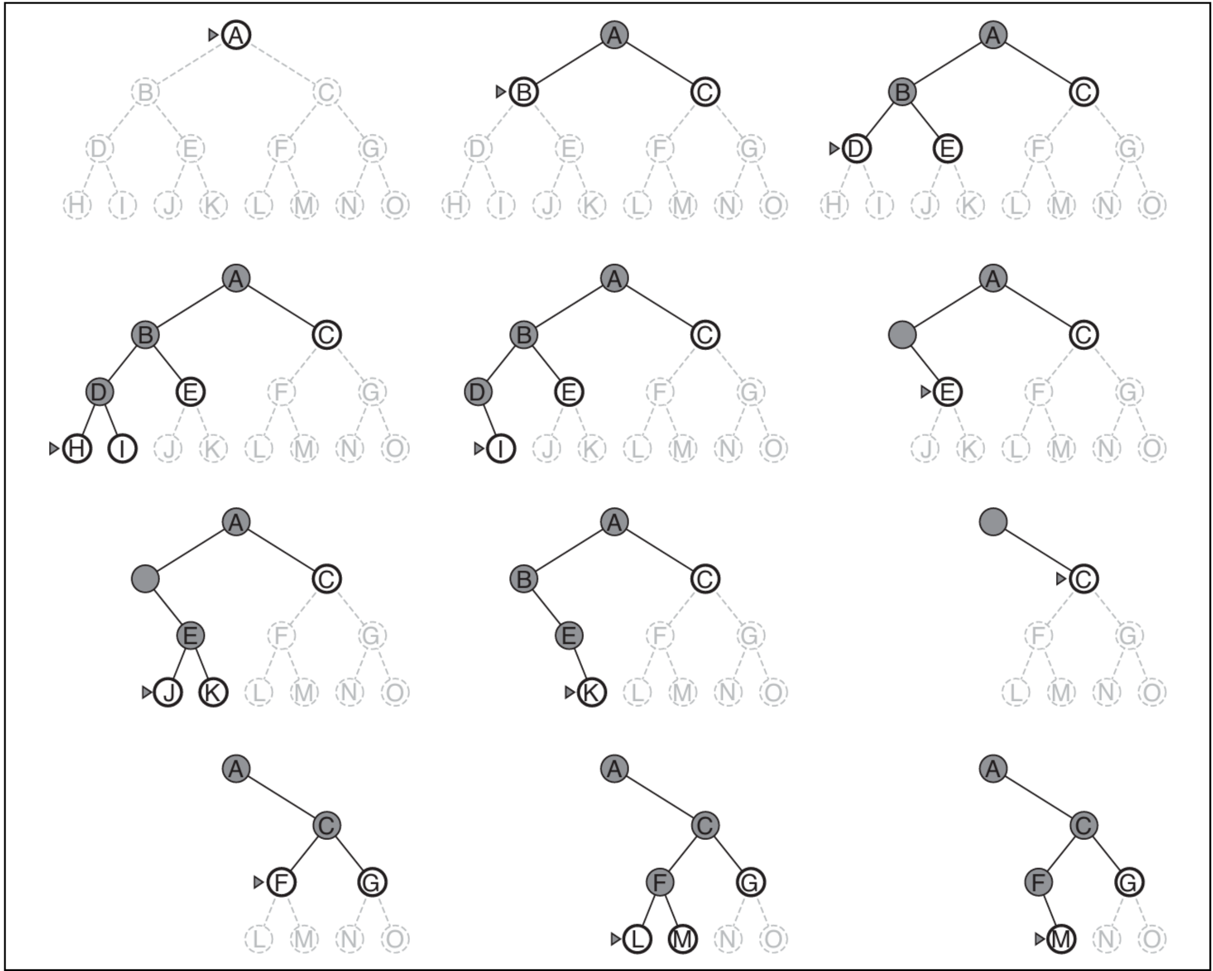
Searching – Romania Map



Depth First Search (DFS)

- DFS explores one branch completely before backtracking to the next branch.

- It lacks BFS's guarantees of finding the shortest path.



Depth First Search (DFS)

- To address DFS limitations:

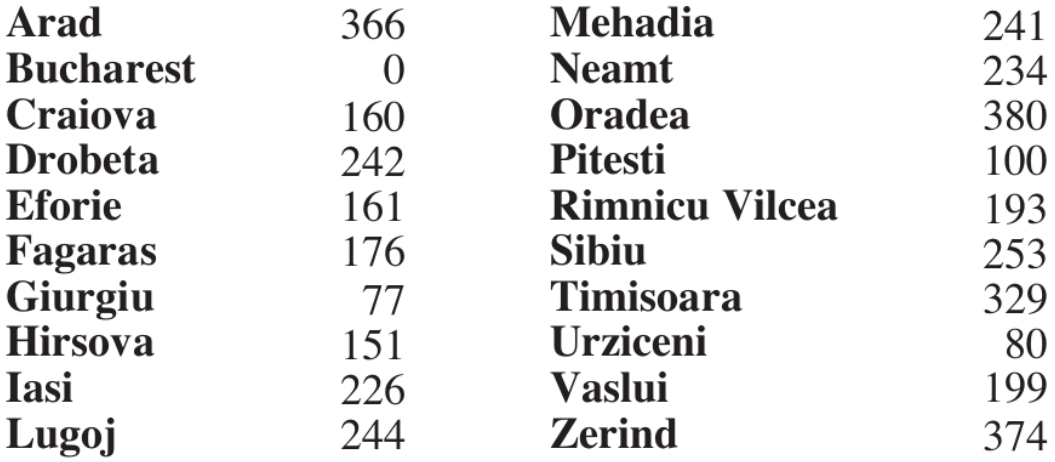
- **Limited Depth-First Search**: Stops expansion beyond a predefined depth, reducing risk of infinite loops.

- **Iterative Deepening DFS**: Gradually increases the search depth, combining the thoroughness of DFS with BFS's optimality.

- **Bidirectional Search**: Runs two simultaneous searches (one from the start and one from the goal) until they meet. This reduces the effective depth to half, with time complexity $\boldsymbol{O}(\boldsymbol{b}^{\boldsymbol{d}/\boldsymbol{2}})$

Informed Search

- **Best First Search:** node is selected for expansion based on an evaluation function, **f(n)**
- **Greedy Best First Search:** Solely based on heuristic function **denoted h(n) = estimated cost of the cheapest path from the state at node n to a goal state.**
- e.g., h(n) = *straight line distance to the goal state*



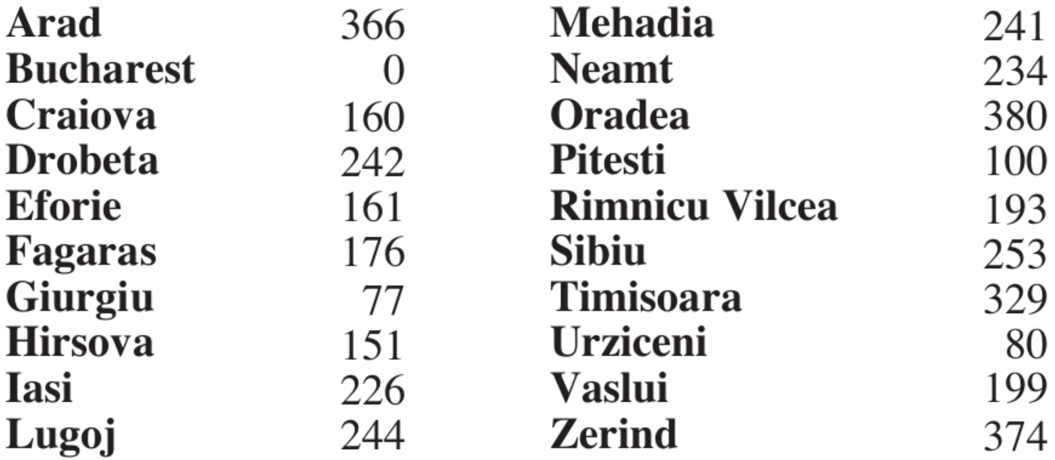
Arad	366	**Mehadia**	241
Bucharest	0	**Neamt**	234
Craiova	160	**Oradea**	380
Drobeta	242	**Pitesti**	100
Eforie	161	**Rimnicu Vilcea**	193
Fagaras	176	**Sibiu**	253
Giurgiu	77	**Timisoara**	329
Hirsova	151	**Urziceni**	80
Iasi	226	**Vaslui**	199
Lugoj	244	**Zerind**	374

A* Search – Minimizing Cost

- Combines both cost to reach the node $g(n)$ and the cost to get from the node to the goal $h(n)$

$$f(n) = g(n) + h(n)$$

- Algorithm is identical to uniform cost search but path cost is now f(n)



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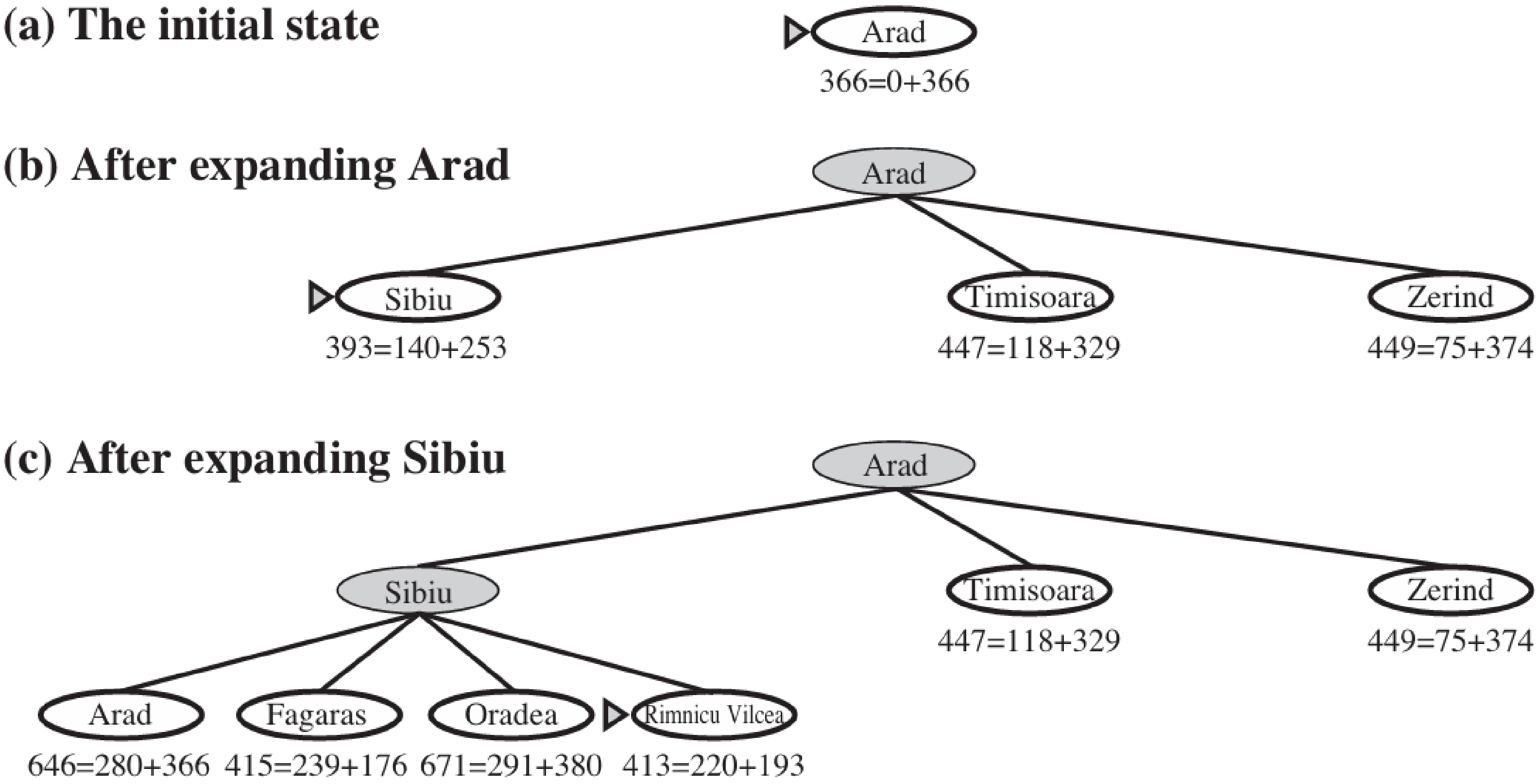
A* Search – Example

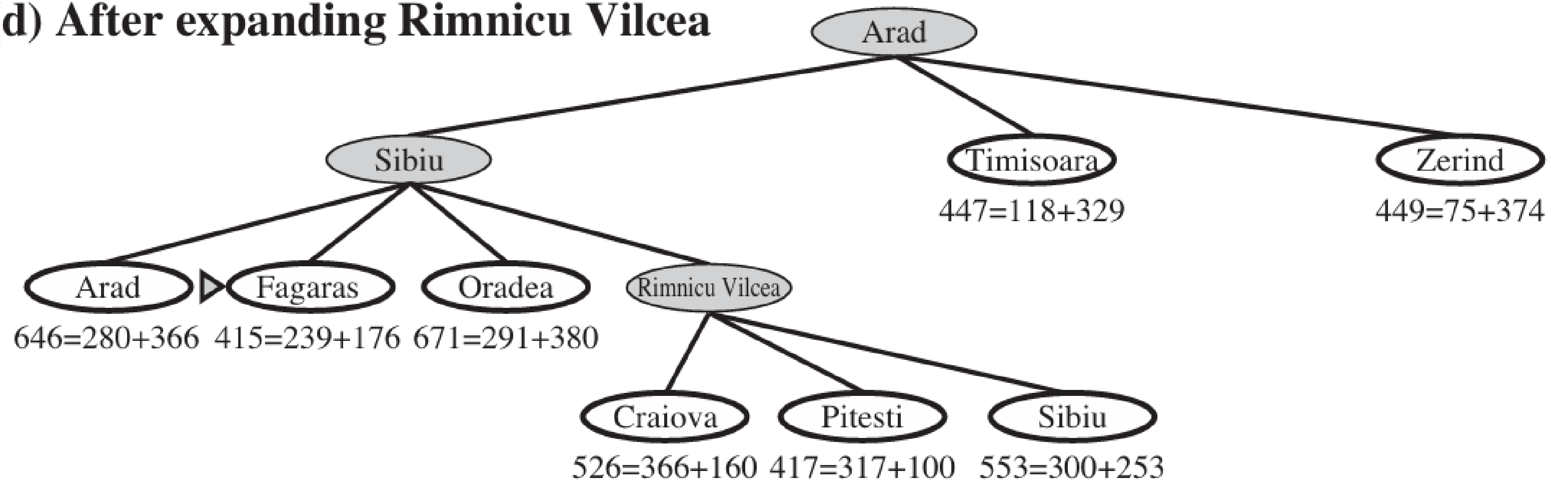


(a) The initial state

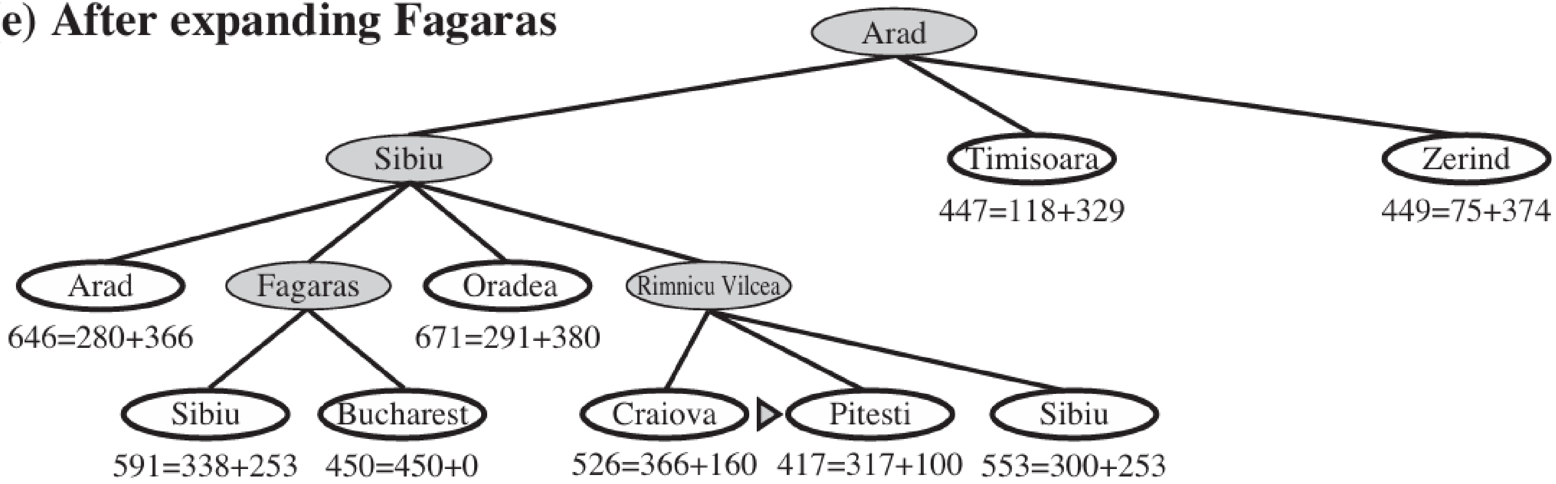
(b) After expanding Arad

(c) After expanding Sibiu

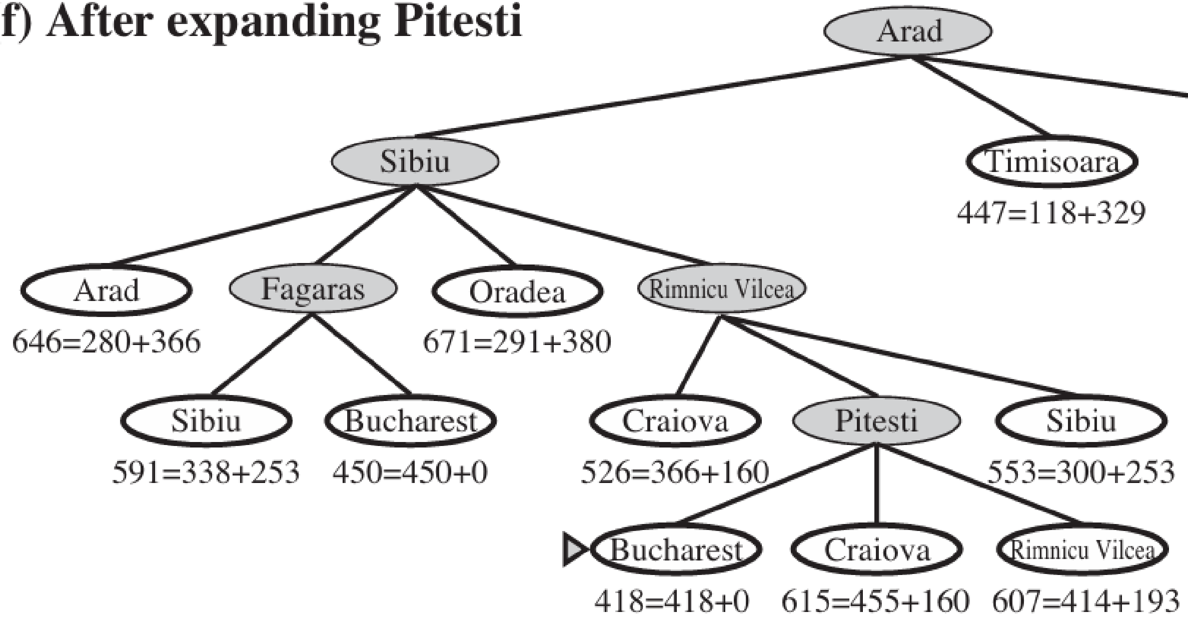
(d) After expanding Rimnicu Vilcea



(e) After expanding Fagaras



(f) After expanding Pitesti



Thank You

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